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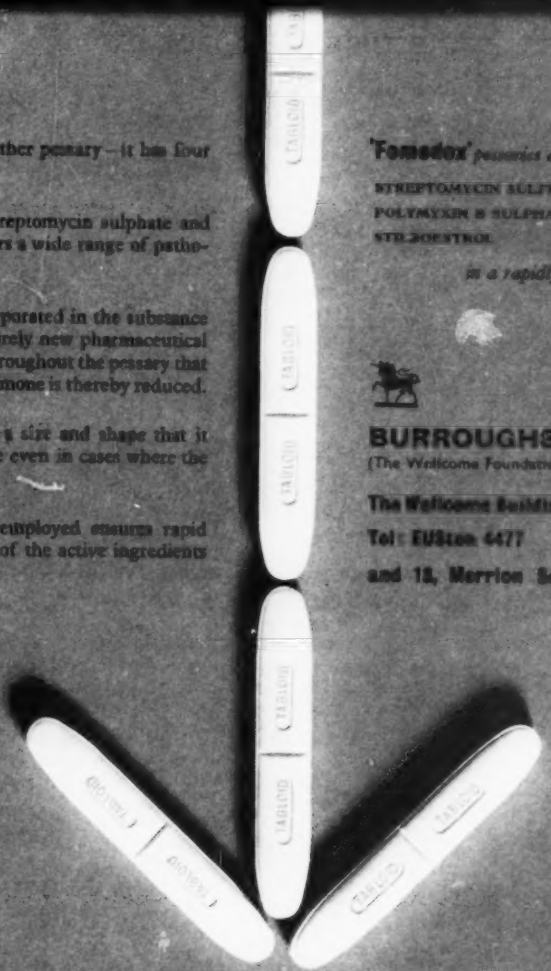

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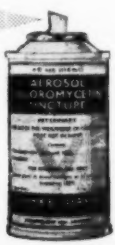

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MAJOR BLOOD ELECTROLYTE CONCENTRATIONS IN CATTLE DURING THE DEVELOPMENT OF HYPOMAGNESAEMIA

By J. R. Todd and R. H. Thompson

Veterinary Research Division, Ministry of Agriculture for Northern Ireland, The Farm, Stormont, Belfast

Fisher (1960) observed that there are very few reports of the simultaneous determinations of the main blood electrolytes in cattle, and reported his investigations into the concentrations of sodium, potassium, calcium, magnesium and chloride in the plasma of healthy Ayrshire cattle.

During the course of a series of investigations into the development of hypomagnesaemia in the bovine species, it was observed that few investigators had made simultaneous determinations of all or most of the major blood electrolytes during hypomagnesaemia, the most extensive investigations being the original studies of Sjollema and Seekles (1929), Sjollema (1930), Dryerre (1932), and the more recent work of Bartlett and co-workers (1957). We therefore made a series of analyses of samples of blood from cows and calves during periods when the blood serum magnesium levels fell from normal to severely hypomagnesaemic levels. The constituents studied were calcium, magnesium, sodium, potassium, chloride and carbon dioxide combining power (alkali reserve).

EXPERIMENTAL METHODS AND MATERIAL

Cows. The cows from which the blood samples were taken were from the herd of the Agricultural Research Institute for Northern Ireland, and although hypomagnesaemic tetany has occurred in the herd it is not a serious problem. The cows were Ayrshire-Shorthorn crosses and all were lactating at the time of the experiment. Samples were taken before the cows went out to pasture and on seven occasions after going out.

Calves. Four Ayrshire bull calves were used in the experiment. During their first week of life they received whole milk, but from the second week their diet consisted entirely of low-magnesium milk prepared by the method described previously (Todd & Rankin, 1959). Blood samples were taken at weekly intervals or more often as hypomagnesaemia developed.

Two samples of blood were taken from each animal by jugular puncture on each occasion, one into a tube containing calcium heparin, for plasma separation, and one into a clean bottle for serum separation. The heparinised samples were centrifuged within 1½ hours of collection and plasma separated. No increase in potassium content of plasma takes place up to 3 hours after collection into heparin, though leakage of potassium from the cells takes place on clotting for a similar period, none of the other constituents being affected. An example of the results obtained from heparinised and clotted samples drawn at the same time is given in Table I. The serum from the clotted sample contains appreciably more potassium than the plasma from the heparinised samples.

TABLE I

EFFECT OF METHOD OF SEPARATION ON PLASMA SODIUM AND POTASSIUM

Sample	*Heparinised*			*Clotted*
Separated after	½ *hour*	1½ *hours*	3 *hours*	3 *hours*
Sodium, m-equiv./l.	147·3	145·7	145·3	147·3
Potassium, m-equiv./l.	4·89	4·89	4·87	5·16

The heparinised plasma was therefore used for sodium, potassium, chloride and carbon dioxide combining power estimations and the serum for calcium and magnesium estimations.

Analytical Methods

Calcium and magnesium were determined on serum by direct ethylenediaminetetra-acetic acid (EDTA) titration (Todd, 1959). Sodium and potassium were determined on an EEL flame photometer at dilutions of 1:100 and 1:50, respectively. Chloride was determined by the method of Schales and Schales (1941), except that the plasma was titrated in a medium of 0·01 N-nitric acid. This gives a sharper end-point to the titration. Carbon dioxide combining power was determined by the volumetric method of Van Slyke as detailed by King & Wootton (1956).

RESULTS AND DISCUSSION

Cows

The results for the cows are set out in Table II as averages for the 18 cows on each sampling date. The cows went out to pasture on 28th April and remained on the same field continuously during the period of the experiment.

The serum magnesium levels dropped markedly within two days of the cows going out to pasture, five of the eighteen cows showing levels of less than 1 mg. per 100 ml. No clinical symptoms were observed, however, even though one cow had a serum magnesium level of less than 0·5 mg. per 100 ml. for more than one week. Samples taken after seven and ten days at pasture showed that the average magnesium level increased after the initial fall, and after 14 days the average had returned to the level found when the cows were indoors.

TABLE II

AVERAGE ELECTROLYTE CONCENTRATIONS OF THE BLOOD PLASMA AND SERUM OF COWS (18)

	27th April	*30th* April*	*4th March*	*7th March*	*14th March*	*21st March*	*28th March*	*4th June*	*Fisher* (1960) *Average normal cows*
Serum magnesium, mg. per 100 ml.	2·19 ±0·31	1·29 ±0·47	1·62 ±0·52	1·80 ±0·52	2·16 ±0·29	2·24 ±0·24	2·41 ±0·27	2·44 ±0·26	1·75
Serum calcium, mg. per 100 ml.	8·81 ±0·82	9·92 ±0·84	9·18 ±0·50	10·49 ±0·82	9·91 ±0·50	10·19 ±0·52	9·89 ±0·42	10·30 ±0·69	10
Plasma sodium, m-equiv. per l.	144·8 ±3·2	144·4 ±1·9	141·4 ±2·2	143·5 ±1·4	142·5 ±1·4	146·6 ±2·4	145·0 ±3·2	146·9 ±2·9	142·2
Plasma potassium, m-equiv. per l.	4·86 ±0·40	4·41 ±0·41	4·55 ±0·45	4·46 ±0·36	4·20 ±0·38	5·03 ±0·53	4·76 ±0·28	4·84 ±0·41	4·4
Plasma chloride m-equiv. per l.	104·9 ±2·2	103·5 ±2·5	102·2 ±3·4	105·0 ±2·4	102·7 ±3·2	106·9 ±2·7	106·6 ±2·7	109·2 ±3·1	103·3
Plasma carbon dioxide combining power, m-equiv. per l.	26·0 ±2·2	26·0 ±2·6	27·7 ±1·8	28·5 ±1·4	26·3 ±2·5	26·8 ±2·3	25·9 ±2·5	25·6 ±2·1	—

*Cows went to pasture on April 28th

The average levels of the other blood constituents tended to fluctuate after the cows went to pasture, though none of these changes paralleled the changes in blood serum magnesium. Only a very few individual analyses showed results outside the accepted normal ranges, and these were isolated cases not confined to either one animal or to one sampling date.

The sodium, potassium and chloride results are in agreement with the previous work on hypomagnesaemic cows. Sjollema (1930) analysed blood from clinical cases of hypomagnesaemic tetany and found sodium levels to fluctuate slightly more than in normal animals, potassium to be normal and chloride to be either normal or slightly low. Dryerre (1932), in an almost identical study, found normal or slightly low sodium levels, normal or slightly elevated potassium levels and normal or slightly low chloride levels, and, more recently, Bartlett and co-workers (1957) found no change in either sodium or potassium levels in hypomagnesaemic cows (but not necessarily showing clinical symptoms). Though none of these previous workers estimated carbon dioxide combining power, the constancy of the results obtained from these cows suggests that it is not affected during hypomagnesaemia.

The final column in Table II shows Fisher's (1960) average results for normal Ayrshire cows and it can be seen that the plasma levels agree closely with those found in the present experiment, even those for 30th April when hypomagnesaemia was most severe.

Calves

During the latter half of the experiment, when the calves were severely hypomagnesaemic, hypersensitivity was evident in all, but no violent symptoms were observed, and all the animals survived the experiment.

The blood electrolyte concentrations during the experiment are set out in Table III as averages for the four calves.

TABLE III

BLOOD ELECTROLYTE CONCENTRATIONS OF CALVES DEVELOPING HYPOMAGNESAEMIA (AVERAGES OF 4 CALVES)

Age of calves (weeks)	*Serum*		*Plasma*			
	Mg mg./100 ml.	*Ca* mg./100 ml.	*Na* m-equiv./l.	*K* m-equiv./l.	*Cl* m-equiv./l.	CO_2–*C.P.* m-equiv./l.
1	2·14	11·52	142·7	6·7	96·5	32·1
2	1·76	11·20	143·3	6·8	96·7	33·6
3	1·43	10·98	145·7	6·2	96·3	35·9
4	1·40	9·80	146·5	5·9	100·0	32·0
5	1·19	9·54	139·2	5·1	101·8	31·7
6	1·16	10·44	144·2	5·2	102·6	34·2
7	0·95	10·44	146·3	5·5	104·7	32·9
8	0·83	10·01	144·9	6·1	102·2	32·6
9	0·82	10·52	144·8	4·8	101·2	32·7
10	0·83	10·66	140·5	4·9	103·2	31·8

The serum magnesium levels fell rapidly and from the seventh week onwards were at or below 1·0 mg. per 100 ml. in all calves. There were, however, no parallel changes in the level of any of the other constituents studied. The calcium and sodium levels and carbon dioxide combining power remained quite consistent throughout the experiment, the calcium and sodium levels being similar to those found for adults. The carbon dioxide combining power of the plasma of all calves remained very constant throughout the experiment, but comparison with Table II shows that the levels are consistently higher than the levels found for cows, by about 6 m-equiv. per litre. This is in agreement with determination of plasma carbon dioxide combining power on normal calves (Dukes, 1955).

The plasma potassium levels during the first three weeks of life were extremely high, individual levels of more than 7 m-equiv. per litre being recorded on a number of occasions. It is interesting to note that Greatorex (1954) found high packed cell volumes, red cell counts and haemoglobin levels in the blood of young calves, and that these levels decreased during the first few weeks of life. It would appear that plasma potassium behaves in a similar manner, and since sodium is not similarly affected it may be that diffusion from the potassium-rich cells maintains an elevated plasma level. Even after these initial high levels, the calves maintained levels higher than the adults, the overall average for the calves from the 5th to 10th weeks being 5·2 m-equiv. per l. as compared to 4·6 m-equiv. per l. for the cows.

In contrast to the potassium level, the plasma chloride level was lower during the first three weeks of life than subsequently. The levels remained fairly constant from the 5th week to the 10th week but the levels were slightly lower than the corresponding adult levels.

These changes in plasma potassium and chloride levels appear to be associated with the very young animal and the differences between the adult levels and those found in the calves from the 5th week onwards are not apparently associated with the hypomagnesaemia, since Fisher (1960) found corresponding differences in normal animals.

The plasma electrolyte levels from the fifth week of life onwards agree with previously recorded results for normal calves and in Table IV the averages for this experiment are compared with those of other investigators.

TABLE IV

PLASMA ELECTROLYTE LEVELS OF CALVES
(AVERAGES QUOTED IN M-EQUIV. PER L)

	Dukes	*Fisher*	*Present series*
Sodium	—	141·8	143·3
Potassium	—	5·1	5·3
Chloride	—	100·3	102·6
CO_2–C.P.	32·7	—	32·6

There is close agreement with published normal levels, even though the average serum magnesium level of the calves during this period was 0·96 mg. per 100 ml.

SUMMARY

1. Blood serum or plasma was analysed (a) from cows developing hypomagnesaemia (without clinical symptoms) on going out to pasture in spring, and (b) from calves developing hypomagnesaemia on low-magnesium milk rations.
2. The analyses included serum magnesium and calcium and plasma sodium, potassium, chloride and carbon dioxide combining power.
3. There were no consistent alterations in the concentrations of any of the other electrolytes consequent upon severe hypomagnesaemia.

ACKNOWLEDGEMENTS

We wish to acknowledge the assistance given to us by the Director and staff of the Agricultural Research Institute for Northern Ireland for putting the dairy cows at our disposal, to Mr. J. E. F. Rankin for taking blood samples and to Messrs. B. Surgenor and D. Robinson for technical assistance.

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ARTIFICIAL INSEMINATION OF PIGS IN JAPAN

By J. H. Riddell-Swan

Department of Agriculture, Hong Kong

In Japan, research work on the artificial insemination of pigs is fairly far advanced but the employment of the technique as a practical breeding measure in the field is still in the initial stages and is in most cases a subsidiary of already-established artificial insemination schemes for cattle. The national government is strongly encouraging the development of artificial insemination in pigs and is backed in this by the many agricultural co-operative societies which play a great part in the economics of Japanese agriculture.

Artificial insemination of pigs is a breeding technique well-suited to the almost peasant type of agriculture mainly practised in Japan as many of these small farmers cannot afford to keep a boar and have to resort to the use of a travelling boar which is often an unsatisfactory type of animal. Despite all this, less than 11 per cent of sows in Japan were being artificially inseminated in 1958.

In the field the boar semen is, whenever possible, collected fresh, divided into doses of 50–60 ml. and used undiluted. The semen can, however, be diluted and under suitable conditions transported over long distances. Samples of diluted semen have already been transported by air from Tokyo to Taiwan and used successfully.

According to Japanese claims, the majority of artificially inseminated sows conceive to the first service but some difficulties are being encountered in the field, not the least of which is the difficulty of determining the correct time for service.

In Japan 90 per cent of the pig population is of the Middle White Breed and the remaining 10 per cent is mainly Berkshire. Consequently most of the A.I. working in pigs has been carried out on Middle Whites.

The Animal Reproduction Unit of the National Institute of Agricultural Science at Chiba, under the direction of Dr. Niwa, is the main centre for research on artificial insemination in pigs. Dr. Niwa has been engaged on artificial insemination in pigs since 1938 and many of the techniques and much of the apparatus at present in use in Japan were devised by him and can be considered typical of Japanese practice.

THE TECHNIQUE OF ARTIFICIAL INSEMINATION

Training of Boars

The training of boars for semen collection begins when they are approximately eight months old and the animals are usually ready for regular routine collections by the time they are ten months old. Boars to be used for artificial insemination purposes have never been used for natural breeding and are always housed singly. Training is commenced using a dummy sow covered with a pig skin smeared with the urine or vaginal secretions of sows or sometimes even with pig semen, but this pig skin is soon dispensed with and is not used when collections are made from fully trained mature boars. The dummy sow may be made of wood and sacking but the best type has a metal frame (Fig. 1) covered with sponge rubber or any other suitable type of padding.

Collection of Semen

The collection of semen is carried out on the dummy sow using the special Niwa type artificial vagina (Fig. 2). This type of artificial vagina obviates the need for continual pumping to achieve the correct pressure during service. Each part of the apparatus is washed and sterilized in the normal manner and rinsed with a solution of 5–6 per cent glucose saline solution immediately before use. This washing is of special importance in the case of the artificial vagina and no other lubricants are used as sufficient appears to be provided during service by the male secretions.

If the air temperature warrants it, the artificial vagina may be filled with water at a temperature of 40–45°C. but this is rarely necessary in Japan except during winter.

After mounting the penis is directed into the artificial vagina (Fig. 3a) and the first fraction of the ejaculate, which is rather colourless, is discarded. As the second fraction, which is milky-white, appears it is collected (Fig. 3b) together with gel fraction. The average time of ejaculation is 6–7 minutes but this varies considerably in different individuals. The average ejaculate is about 250 ml. of which roughly 20 per cent is gel. The gel is separated immediately by filtration through gauze, and the semen is examined.

Semen Examination

The volume of the semen is measured and an initial naked eye examination is made for gross pathological changes. The pH is then tested using bromothymol blue paper. The pH is usually between 6·7 and 7·3. Microscopic examination is carried out on a heated microscope stage at 37°C. for morphology and activity. A sperm count is made using a haemocytometer. The normal average number of spermatozoa is about 200–250 million per ml. but there is considerable variation.

Storage, Transportation and Distribution of Semen

The filtered semen is stored at 15–20°C. until used and should be kept at this temperature during transportation. Transportation is carried out in special

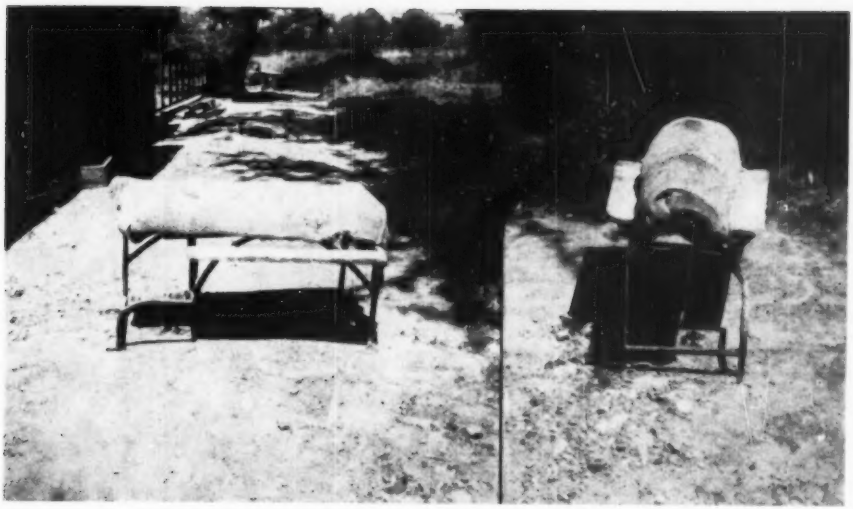

FIG. 1. Dummy sow used for collection of semen.

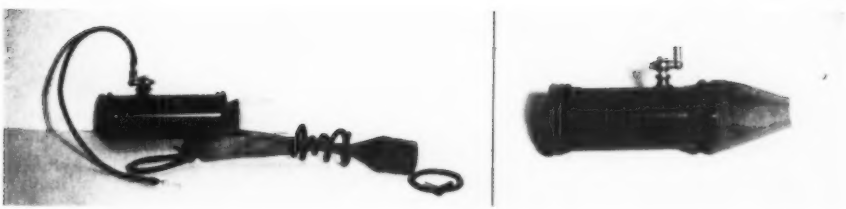

FIG. 2. Artificial vagina.

THE TECHNIQUE OF ARTIFICIAL INSEMINATION

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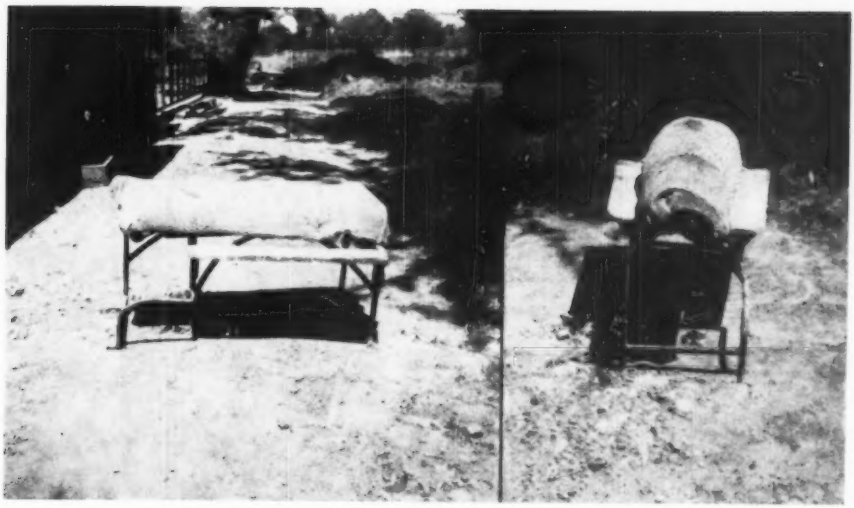


FIG. 1. Dummy sow used for collection of semen.

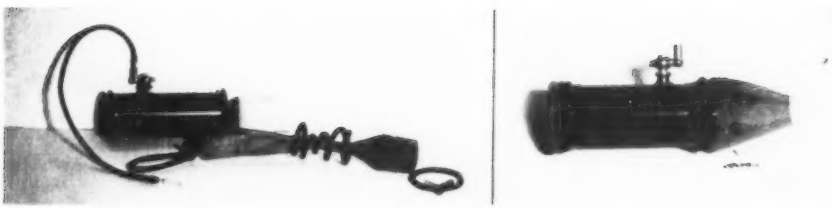
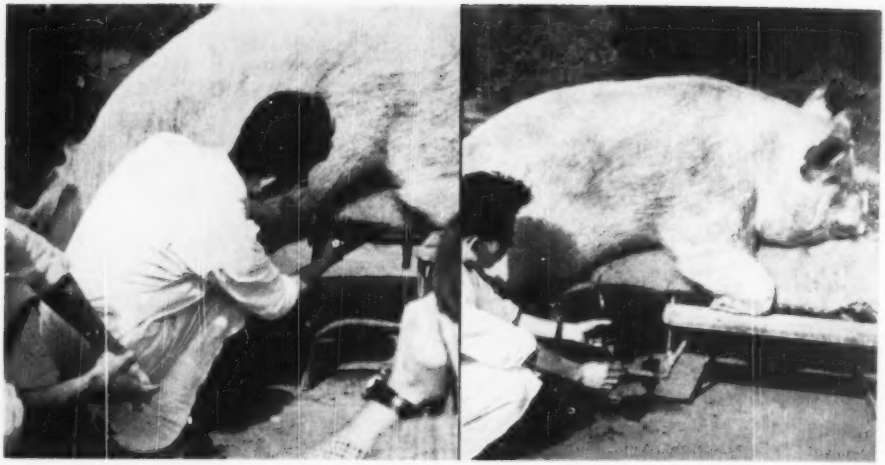


FIG. 2. Artificial vagina.



(a) (b)

FIG. 3. Collection of semen.

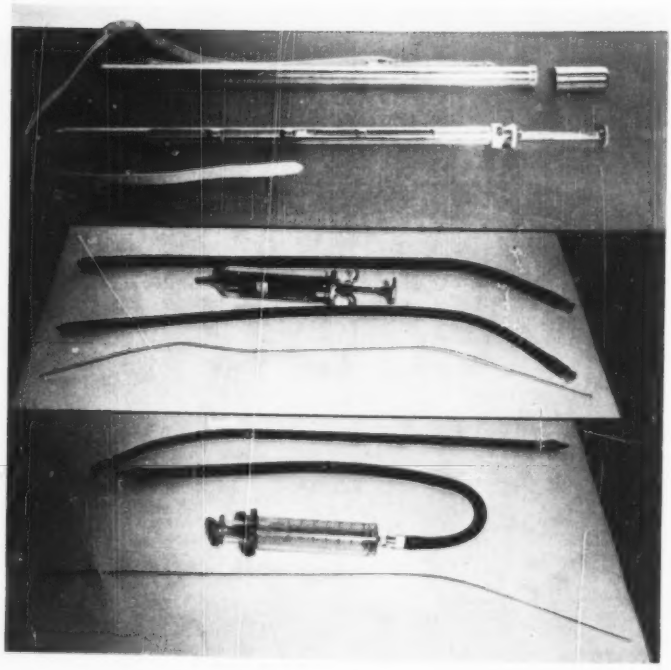


FIG. 4. Insemination syringes.

equipment designed to minimize temperature changes and vibration. Stored semen is periodically checked for motility.

The Japanese workers believe that for the storage of pig semen the best diluent is an egg yolk citrate type containing 6 per cent glucose with 1,000 units of streptomycin per ml. as a bacteriostatic agent. Sodium sulphamerazine (0·2 per cent) and para-amino-methylbenzine sulphonamide (0·1 per cent) are also used as bacteriostatics.

The diluent is made up as follows:

25 ml. egg yolk,

25 ml. 3 per cent sodium citrate solution,

50 ml. sterile 6 per cent glucose solution plus 50,000 units streptomycin.

The semen is diluted with equal quantities of diluent and is stored at 15°C. The addition of this diluent is reputed to extend the viability of the semen to 5–7 days and it was semen diluted in this way that was used in the Tokyo–Taiwan experiment mentioned above.

In Japan dilution of boar semen is rarely practised in the artificial insemination of pigs in the field.

A moderate degree of vibration does not appear to have a great deal of adverse effect on boar semen but it has been found that horizontal vibration is much more lethal than vertical vibration. Prolonged exposure to light has a lethal effect but it is believed that the lethal effect of sunlight is due more to heat than light.

As the result of anabiosis, boar semen may separate into an upper fluid layer and a lower, spermatozoa-rich, layer. This separation does not appear to affect the quality of the semen but when it occurs the semen is warmed and gently shaken before use to reactivate the spermatozoa.

The Insemination of the Sow

As was stated above, it is unusual for boar semen to be diluted for use in the field and normally 3–4 sows are inseminated from one ejaculation, the dose of semen being 50–60 ml. for each sow. The best results have been achieved using this undiluted semen, but if for any reason the semen has to be stored, dilution may be practised. The undiluted semen is satisfactory up to 24 hours from collection and claims of successful results with semen 48 hours old have been made.

The oestrous syndrome in the sow may, according to the Japanese workers, last from 2–7 days and may be divided into three stages, each stage varying greatly in duration.

First stage: Vulva swollen and congested. Vaginal discharge copious and watery.

Second stage: This is the stage of true oestrus. Frequent urination, reduced appetite, mounting of other animals and psychical changes. During this stage the animal will stand for service and this is detected by the erection of the ears and immobility when manual pressure is applied to the lumbo-sacral region.

Third stage: Gradual disappearance of oestrous signs.

Insemination is carried out in the second stage of oestrus during the period of immobility on lumbo-sacral pressure.

Prior to insemination the vulva and perineum of the sow are washed thoroughly and rinsed with normal saline solution. The insemination pipette is then inserted right into the cervix and 50–60 ml. of semen injected as slowly as possible, preferably over a period of at least 1–2 minutes. Various types of insemination pipettes (Fig. 4) such as the metal and glass combined syringe and pipette or the thick rubber type of pipette with or without the glass extremity are in use. It has been found, however, that the best results have been obtained using a rubber pipette with an enlarged extremity.

ORGANIZATION OF ARTIFICIAL INSEMINATION

In Kanagawa Prefecture there has in recent years been a marked trend towards increased specialization in small-scale dairy farming and pig raising. The prefecture has become one of the most important dairying and pig raising areas in Japan and at the Kanagawa Animal Breeding Station there is the nucleus of a field service for the artificial insemination of pigs. Boar semen is also sent from sub-stations in the prefecture for distribution and use.

The organization at Kanagawa is typical of the Japanese system and is as follows:

(1) The farmer notifies the centre that he requires artificial insemination services for his sow.

(2) A veterinarian from the centre then visits the farm to ascertain if the sow is at the correct period of oestrus for insemination.

(3) If the sow is found to be ready for service the veterinarian notifies the inseminator.

(4) The inseminator then visits and inseminates the sow.

Farmers can also bring in their sows to the station for examination and service at a reduced fee.

The system is rather cumbersome and requires a large number of professional personnel but the employment of a qualified veterinarian in the preliminary examination of the sow may be an important factor in the high conception rate reported in the Japanese pig artificial insemination scheme.

The fees charged in Kanagawa are as follows and include repeated free services if conception does not occur:

	Yen	
(1) The sow brought to the station:		
Semen fee (60 ml.)	400	
Station service fee	500	
Total	900	(£1 = 1,000 yen)
(2) The farm visited:		
Semen fee (60 ml.)	400	
Field service fee	700	
Total	1,100	

If the farmer is a member of a co-operative in the area he may get a preferential reduced fee.

The Japanese pig artificial insemination techniques described above have been used in Hong Kong with considerable success since November 1958 and it is hoped that an account of this work will be published in the near future.

ACKNOWLEDGEMENTS

I should like to thank the Government of Hong Kong for permission to publish this article and to express my gratitude to Dr. Saito, Dr. Niwa, Professor Nishikawa, Dr. Ito, and the members of the staff of the Ministry of Agriculture and Forestry for all their help and consideration during my visit to Japan. My thanks are also due to the Japanese Ministry of Agriculture and Forestry, the National Institute of Animal Sciences, Kyoto University and the various prefectual governments, especially the Government of Kanagawa, for permission to visit their various departments and institutes.

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BOVINE ENDOMETRITIS: A REVIEW

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Ministry of Agriculture, Fisheries and Food, Cambridge

An earlier review (Dawson, 1950) on this subject concluded that, up to 1947, no study then made included an attempt to assess the true value of treatment by leaving a proportion of untreated control cases. Failures to respond to treatment had rarely been followed to post-mortem examination or to eventual natural recovery, and no single investigation possessed balance over the various aspects such as bacteriology, clinical symptoms, therapy and post-mortem assessment. The importance of bacteriological control before and after treatment, and of correlation between the status of the animal's oestrous cycle and the clinical appearance of the disease, for such studies, was also particularly stressed (Dawson, 1951). Since 1947 not less than 70 papers have been published on this specific disease problem, a number of which have gone some way towards filling the indicated gaps, while others have been concerned with application of more modern clinical methods. This volume of work attests the great economic importance of the disease. Moore (1954) stated that it was involved in 85 per cent of infertility cases and was thus one of the most important entities in the entire field of veterinary practice, and Schütze (1957) used almost the same words. Hardenbrook (1958) found it was involved in 80 per cent of breeding failures in Illinois, while in the opinion of Anderholm (1958), too, it was the commonest cause of infertility.

CLINICAL CLASSIFICATION OF TYPES OF ENDOMETRITIS

With some minor individual variations, authors have generally retained Richter's (1926) classification according to the type and extent of discharge: absent or intermittent in first degree cases, a continuous mucopurulent type in cases of the second degree, and a purely purulent type with some tendency to accumulation representing the third degree of involvement. Table I gives some indication of the relative proportions in which cases of the different degrees occur. This table shows in all 2,106 first degree cases studied as against 1,347 second and third degree cases. However, since four of the eleven general investigators included a majority of first degree cases, and since certainly Dawson (1949) and Aziz-ud-Din (1948) of the other seven were deliberately selecting a majority of the more serious cases for study, it seems reasonable to conclude that perhaps two first degree cases come to notice for every one more serious, and that second

degree cases possibly exceed those of the third degree in a similar proportion, an overall ratio of 6:2:1 from the first to the third degree. But Shalash (1958) recorded as many as 20 cases of pyometra among abnormal genital organs from 106 buffalo. The large first degree group has become subdivided first into cases which appear clinically normal throughout, but which return to service until apparently responding to treatment; second come those cases which during oestrus produce a discharge which contains some pus or an abnormal bacterial content. Where failure to conceive constitutes the only basis for a clinical pre-treatment diagnosis, the extent of its accuracy can only be assessed later by careful control of the results such methods of treatment achieve. Many such infertility cases must be caused by quite other conditions.

Hemnell (1954) clearly demonstrated, on breeding records and treatment responses, the existence of an important category of disease cases characterized by purulent abnormality of the oestrous discharge—approximately half of those reported for returning to service. Deane and Nayadu (1957) confirmed similarly, in the buffalo, the increased infertility of such cases as compared with cases normal at heat. Moulin (1952), Wunner (1950) and Genegal (1955) also recognized this particular entity, cases of which in Genegal's material were three times as numerous as those returning with normal oestrous mucus. However, Pettersson (1959), analysing 1,036 samples of oestrous mucus, found that the conception rate after 453 inseminations when the mucus contained pus flakes was at least as good as in controls, even when the flakes were large. These good rates in such circumstances were attributed to the effect in recent years of artificial insemination, antibiotics, and longer calving to service intervals in reducing the incidence of endometritis. Renner (1956) had recorded immediate conception in five cows which were freely discharging pus among the oestrous mucus, and Schlaak (1957) recorded similar observations.

Second and third degree cases, most of which had been found to be post-puerperal in origin, were sub-classified by Dawson (1951), who recognized a type of copious purely purulent discharge with characteristic bacteriology of two types, primarily associated with delay in resumption of oestrous cycles. Less specific bacteriological findings and a scantier mixed mucopurulent discharge occurred concurrently with oestrous cycles and in a variety of circumstances. Lundgren (1947) and also Thygesen (1948) had earlier put on record that a purely purulent endometritis was usually a post-puerperal development associated with cycle failure. Wunner (1950) too had observed a group of cases with copious purulent discharge which seemed to correspond closely in its two subgroups with those detailed by Dawson, whose classification, correlating the two main types of discharge with bacteriological content, in itself confirmed the study by Aziz-ud-Din (1948) on post-mortem material. Baurle (1950) described a subgroup with regular cycles, a mixed mucopurulent discharge and poor future breeding prognosis which corresponds closely with one of Dawson's three mucopurulent discharge subgroups in which the cows had previously been infected with *Trichomonas foetus*. This organism occurred among Baurle's material. A group with a good breeding prognosis but with an irregular cycle and mucopurulent discharge was also described by Baurle.

TABLE I. NUMBERS STUDIED OF CLASSIFIED ENDOMETRITIS CASES

	Total Cases	1st degree	2nd degree	3rd degree
Baurle (1950)	49	18	23	8
Pundt (1950)	80	30	25	
Aziz-ud-Din (1948)	81	25	56	
Filsinger (1955)	91	43	48	
Fietzsch (1958)	100	43	53	4
Genegal (1955)	113	58	36	6
Ohm (1955)	120	86	21	13
Evertz (1955)	120	97	15	8
Merkt (1953)	140	128		12
Dawson (1949)	143	79	36	28
Steinborn (1956)	286	93	195	
Anderholm (1958)	751	313	418	
Group Totals		799	1003	

	Total Cases (all 1st degree)
Deane and Nayadu (1957)	67
Easley *et al.* (1951)	80
Hoppe (1955)	117
Smith (1957)	123
Hennell (1954)	156
Sacchi *et al.* (1958)	236
Rottensten & Kierkegaard (1954)	485
Total Cases, all workers	1,314

	Total Cases (no 1st degree) 2nd degree	3rd degree
Boller (1954)		16
Kliemann (1933)	15	3
Thygesen (1948)	60	
Lundgren (1947)	60	
McWilliam (1954)	900	
Total Cases, all workers	354	

TABLE II. PERCENTAGE OF INDIVIDUAL ENDOMETRITIS CASES YIELDING CERTAIN ORGANISMS (IN SECRETION)

Section 1: Single Samples	*No. of cases studied*	*% Sterile*	*Non-haemolytic staphylococci*	*Haemolytic staphylococci*	*streptococci*	*E. coli*	*Ps. pyocyanea*	*C. pyogenes*	*B. proteus*	*Miscellaneous*
Merkt (1953) ..	140	45	—					6		*V. foetus* 2 Moulds 3
Evertz (1955) ..	40	—	33		5	27·5			15	Gram-positive rods (? anthracoids) 27·5
Ohm (1955) ..	40	—				45		9·5	7·5	
Stach (1957) ..	164	—	39 "pyogenes albus"		18 18	27 (includes some *Aerobacter* etc.)		1		Anthracoids 15 *Neisseria spp.* 4
Genegal (1955) ..	44	—			18 haemolytic	64		9·5		
Carotta (1958) ..	90	90	33			9			9	
Rasbech (1950) ..		75			less than 1	7		7		Mixed other bacteria 6
Aziz-ud-Din (1948)	59	8	38		20	20		33		*T. foetus* 5 Other Diphtheroids
Section 2: Samples before and after treatment										
Baurle (1950) ..	49	—	60 "2 varieties"		?					*T. foetus* 22 Diplococci 16
Koch *et al.* (1958) ..	93 (186 samples)	—	?	removed by treatment					11	Anthracoids 60 unaffected by treatment
Easley *et al.* (1951)	40 (89 samples)	20			40 non-haemolytic		8 (15 at post-mortem)	7–18 "Diphtheroids" 100 (removed by treatment)		
Boller (1954) ..	16									
Section 3: Continuous periodic sampling										
Dawson (1949) ..	143 (447 samples)	8	50 (1) *	11	47 (8) α-haemolytic	61 (31) (haemolytic 10 (5))	1 "very many"	94 (41) (removed by treatment)	10	Anthracoids 20 *Neisseria* 3 Moulds 3 Other Diphtheroids 4 Other Coliforms 1 *M. tuberculosis* 1

* Figures in brackets indicate numbers of culture plates with the organism in very high density

THE BACTERIOLOGY OF ENDOMETRITIS

Relatively few workers have concerned themselves with this aspect of endometritis. Table II shows in section 1 results by ten investigators who made a single culture from each cow (often only a proportion of the total of cows they studied in other ways). Section 2 includes results from four sources where each cow was sampled twice, before and after treatment, and section 3 shows results where each cow was sampled continuously over a period, the average being more than three times with over 50 cows sampled at least five times each. Table III includes results from cervical swabbing only of first degree endometritis cases.

All these sets of observations possess many features in common, beyond which may be distinguished certain groupings according to the particular circumstances affecting the workers in question. At the outset some explanation is possible for the greatly varying proportion of cases from which no organisms were recovered. The high percentages reported by Rasbech (1950) and by Kiesel & Dacres (1959) can be accounted for, respectively, by the high dilution of organisms in lochial samples not many weeks after calving, and by the probable low efficiency of cervical swabbing as a method of recovery of organisms, in contrast to culture from samples of discharge. When as many as six to 12 samples per cow are taken (Table II, section 3), the proportion of animals yielding no organisms is considerably reduced, as contrasted with series of cows sampled only once or twice each.

There is general agreement that the most usual members of the flora are staphylococci and *Escherichia coli;* non-haemolytic staphylococci occur on the whole rather more frequently than haemolytic strains though these exclusively were found by five workers. Streptococci, usually α or β haemolytic, are not much less common, and in six of the fifteen publications a large proportion of anthracoids were reported: *Bacillus proteus*, *Pseudomonas pyocyanea*, and *Neisseria* species occur rather consistently as minority organisms. Comparison with a similar table of organisms recovered from the uteri of normal cows (Dawson, 1959) indicates that the percentage of "organism-free" cows falls steeply in the presence of disease, and that there is a distinct rise in recoveries of both types of staphylococci and of *E. coli*, a considerable rise in *Corynebacterium pyogenes* and a slight rise in streptococci. The anthracoids and minority organisms are proportionally little changed.

The great variation in the proportion of *C. pyogenes* recovered reflects the different interests of the various workers. High or greatly increased proportions of *C. pyogenes* recoveries were reported by Rasbech (1950), Easley, Leonard and Trotter (1951) and particularly Aziz-ud-Din (1948), and Dawson (1949, 1951). Aziz-ud-Din's survey was a purely autopsical one on random abattoir material involving culture mainly from obviously diseased genitalia; thus there was selection of what would be the worst cases clinically. The work of Rasbech, Easley *et al.*, and Dawson was very explicitly non-selective, calculated to give a reasonable approximation to the true incidence of the different disease types (although in the later stages some selection of *C. pyogenes* cases was practised by Dawson). In general under these circumstances 15–40 per cent of endometritis

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Evertz (1955)	120	97	15	8
Merkt (1955)	140	128		12
Dawson (1949)	143	29	36	78
Steinborn (1956)	288	93	195	
Anderholm (1958)	731	313	418	
Group Totals		792	993	

	Total Cases (all 1st degree)
Deane and Nayadu (1957)	67
Easley *et al.* (1951)	80
Hoppe (1955)	117
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Genegal (1955) ..	44	—		66	18 haemolytic	64		2·5		
Cartella (1958) ..	30	30	53			9			9	
Rasbech (1950) ..		75			less than 1	7		7		Mixed other bacteria 6
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Relatively few workers have concerned themselves with this aspect of endometritis. Table II shows in section 1 results by ten investigators who made a single culture from each cow (often only a proportion of the total of cows they studied in other ways). Section 2 includes results from four sources where each cow was sampled twice, before and after treatment, and section 3 shows results where each cow was sampled continuously over a period, the average being more than three times with over 50 cows sampled at least five times each. Table III includes results from cervical swabbing only of first degree endometritis cases.

All these sets of observations possess many features in common, beyond which may be distinguished certain groupings according to the particular circumstances affecting the workers in question. At the outset some explanation is possible for the greatly varying proportion of cases from which no organisms were recovered. The high percentages reported by Rasbech (1950) and by Kiesel & Dacres (1959) can be accounted for, respectively, by the high dilution of organisms in lochial samples not many weeks after calving, and by the probable low efficiency of cervical swabbing as a method of recovery of organisms, in contrast to culture from samples of discharge. When as many as six to 12 samples per cow are taken (Table II, section 3), the proportion of animals yielding no organisms is considerably reduced, as contrasted with series of cows sampled only once or twice each.

There is general agreement that the most usual members of the flora are staphylococci and *Escherichia coli;* non-haemolytic staphylococci occur on the whole rather more frequently than haemolytic strains though these exclusively were found by five workers. Streptococci, usually α or β haemolytic, are not much less common, and in six of the fifteen publications a large proportion of anthracoids were reported: *Bacillus proteus*, *Pseudomonas pyocyanea*, and *Neisseria* species occur rather consistently as minority organisms. Comparison with a similar table of organisms recovered from the uteri of normal cows (Dawson, 1959) indicates that the percentage of "organism-free" cows falls steeply in the presence of disease, and that there is a distinct rise in recoveries of both types of staphylococci and of *E. coli*, a considerable rise in *Corynebacterium pyogenes* and a slight rise in streptococci. The anthracoids and minority organisms are proportionally little changed.

The great variation in the proportion of *C. pyogenes* recovered reflects the different interests of the various workers. High or greatly increased proportions of *C. pyogenes* recoveries were reported by Rasbech (1950), Easley, Leonard and Trotter (1951) and particularly Aziz-ud-Din (1948), and Dawson (1949, 1951). Aziz-ud-Din's survey was a purely autopsical one on random abattoir material involving culture mainly from obviously diseased genitalia; thus there was selection of what would be the worst cases clinically. The work of Rasbech, Easley *et al.*, and Dawson was very explicitly non-selective, calculated to give a reasonable approximation to the true incidence of the different disease types (although in the later stages some selection of *C. pyogenes* cases was practised by Dawson). In general under these circumstances 15–40 per cent of endometritis

TABLE III. PERCENTAGE COMPOSITION OF POSITIVE CERVICAL SWAB CULTURES IN FIRST-DEGREE ENDOMETRITIS CASES

	No. of Cases Studied	*% Sterile*	*Non-haemolytic staphylococci*	*Haemolytic staphylococci*	*Streptococci*	*E. coli*	*Ps. pyocyanea*	*C. pyogenes*	*B. proteus*	*Miscellaneous*
Kiesel & Dacres (1959)	1,359	72	20	4·5	29 mostly haemolytic	12		0·5	1·5	Anthracoids 8 *V. fetus* 7 Other vibrios 9 Diplococcus 0·5
Vigue *et al.* (1959)	66	None	—	12	17 (haem.) 29 (others) 46 (total)	23	13	7	6	Anthracoids 11 Other coliforms 49

TABLE IV. ANTIBIOTIC PROPHYLAXIS AGAINST ENDOMETRITIS

	Antibiotic etc.	*Details of administration*	*No. of treated cases*	*No. of controls*	*Services per conception—treated cases*	*Services per conception—control cases*	*Remarks*
Jorgensen (1959)	Dihydrostreptomycin	1 g. 12 days after calving			2·1	2·9	All animals treated; control figures average for previous years (1944–54)
Jorgensen (1959)	Terramycin	0·5 g. 10 days after calving					Some *V. fetus*-infected bulls in use during control period
Huber (1957)	Lyophilized calcium glucose terramycin complex	100 mg. 20–45 days after calving	37		1·46	2·18	Bases of selection between controls and treated cases not detailed
Buckalew & Alford (1958) ..	Penicillin Streptomycin	500,000 units: 1 g. during heat *previous to* service	89	89	1·3	1·8	
Stula, Plastridge & Jungherr (1958)	Aureomycin	2×0·5 g. within 24 hours of calving	30	30	1·7	2·3	*V. fetus*-infected herd Same control group
Stula *et al.* (1958)	Neomycin	1 g. within 24 hours of calving	30	30	2·0	2·3	
Vigue *et al.* (1959)	(Nitrofurazone)	2 intravaginal pessaries twice weekly for a month before service. (Amount unknown)	265	265	1·88	2·85	
Hinze (1958)	Terramycin	2 g. within 24 hours of calving	75	79	2·24	1·67	Same control group
Hinze (1958)	Neomycin plus sulphathiazole	Within 24 hours of calving (Amount unknown)	74	79	2·56	1·67	
Brown, Pfau, Mather & Bartlett (1959)	Aureomycin	0·5 g. within 24 hours of calving	84	96	1·78	1·47	Depression of conception rate

cases may perhaps be associated with *C. pyogenes*. It has been mentioned previously (Dawson, 1950) that by 1944 a tradition had arisen in Germany that in such cases prognosis was always so bad that treatment was not usually worth attempting, and consequent elimination at the outset of such cases from their treatment trials might well account for the low incidence of *C. pyogenes* reported in the nine German papers from which material is included in Table II, and thus also *C. pyogenes* is low in the purely first-degree endometritis cases of Table III. There have however been others who have been interested exclusively in this type of disease (Thygesen, 1948; Boller, 1954; Agrimi, d'Ascani & Tozzini, 1959; Beer, 1959; and Bulling, 1954).

Further evidence in favour of the pathogenic importance of *C. pyogenes* is provided by Boller's (1954) and Dawson's (1951) success in eliminating it by treatment, with ensuing improvements in fertility, and by its occurrence in very high density on 41 of Dawson's (1949) 51 positive culture plates.

Additional information on the importance of the other possible pathogens is available from the very careful typing of coccal strains carried out by Kiesel and Dacres (1959), who found two out of 17 strains of haemolytic staphylococci to be coagulase-positive and hence among the most clearly pathogenic members of this genus. Kampelmacher (1954) also reported that most of the staphylococci he found in a random abattoir sample of uteri were positive to this test, and Calaprice (1958) distinguished pathogenic staphylococci in bovine genitalia as well as saprophytic strains. Among the streptococci Kiesel & Dacres found 12 strains which they claimed to be *Strep. pyogenes*, two to be *Strep. agalactiae* and ten from Lancefield's group C, all of which are usually considered pathogenic. Of these only *Strep. pyogenes* has been recorded from the normal cow uterus (Gunter *et al.*, 1955) and then as an isolated instance. As regards these organisms, Dawson (1949) found that only four out of 50 plates on which there were staphylococci yielded the organism in very high density, and eight out of 47 plates showing streptococci, though the proportion was higher (three out of 11) for haemolytic staphylococci. But on 31 of 61 plates with *E. coli* the density of colonies was very high. In spite of the possibility that *E. coli* may simply be a contaminant the evidence summarized in Table II suggests that *E. coli* may be pathogenic and this is possibly supported by the haemolytic properties of ten of the strains recovered by Dawson (1949), of which five were present in large numbers.

Merkt (1953), Ohm (1955), Evertz (1955), Genegal (1955), Baurle (1950), Dawson, Kiesel & Dacres all agreed that mixed cultures were the general rule (70 per cent); most of these workers found an average of two genera per sample whereas Dawson (1949) found nearly four and Kiesel & Dacres seven but it is probable that only Kiesel & Dacres employed a fully adequate technique. There does seem to be some support, e.g. Schütze (1957), for the common conception that many endometritis cases are associated with mild pathogenic action by several different organisms, outstandingly staphylococci, streptococci and possibly some strains of *E. coli*. There seems no reason not to regard the anthracoid organisms which are frequently recovered as contaminants, and the *B. proteus*, diplococci, "other diphtheroids and coliforms" and possibly

members of the *Neisseria* species as survivors of the normal uterine flora. Evertz (1955), however, considered that *B. proteus* could produce serious effects, and Lindley & Hatfield (1952) found a high incidence of *Neisseria* species in a short series of infertile cows, and agglutination reactions up to 1:640.

Regarding *Ps. pyocyanea*, a quite extensive specialist literature exists, e.g. Wunner (1950), von Stellmacher (1954), Corrias & Molinari (1959), tending to the conclusion that this organism is not infrequently a facultative pathogen spread venereally. A first degree endometritis with pus in the oestrous mucus seems to be regarded as typical.

Of the major specific uterine pathogens, *Brucella abortus* is not mentioned in Tables II and III as herds so infected have been deliberately excluded from consideration by most research workers. *Vibrio fetus* occurs in these tables only sporadically, as only a minority of workers used adequate culture methods. Probably its undiagnosed occurrence forms an undeniable source of inaccuracy in most of the results discussed. *Trichomonas foetus*, less readily missed, appears more often but is now of steadily decreasing importance and on good evidence did not occur in the material studied by Kiesel & Dacres, or by Dawson, except where specified. The main need at present might be held to be for more intensive and comprehensive study of the type of second and third degree endometritis associated, so far rather tenuously, with such organisms as haemolytic strains of *E. coli* and the staphylococci, along the lines already indicated by Thal, Bane & Bakos (1959) and by Laing & Downe (1946).

THE RELATIONSHIP OF ENDOMETRITIS TO THE OESTROUS CYCLE

Although by definition first degree cases occur in the presence of a normal cycle, work reviewed earlier (Dawson, 1950) already showed clearly that abnormalities of the ovarian cycle are common in the more severe degrees of the disease, and that re-initiation of a cycle was a useful therapeutic aid. There had been some controversy as to whether ovarian or uterine abnormality was the primary condition, with the balance of evidence inclining in the end towards indicating the ovary as the organ primarily affected. It was known that cycles could be successfully re-initiated or reset by mechanical or chemical stimulation of the cervix or by enucleation of the corpus luteum. Later it was shown, in two instances involving short series of pyometra cases, that they could be re-initiated by the use of synthetic oestrogens.

More recently, apart from some of those workers whose interest has been restricted to the first degree type of case, there has been general agreement that an important proportion of cases arises in the few weeks following calving before heat recurs. Thus all of the cases studied by Pietzsch (1958), Cartella (1958), Evertz (1955), Ohm (1955), Boller (1954), Nielsen (1949), Waddington (1951), Orton (1954) and McWilliam (1954), originated in this post-puerperal period. All these authors included a proportion of second and third degree cases, relatively low in the series of Ohm and of Evertz (Table I), but constituting a majority, or the whole of the series, in the others. Schaetz (1950) had the impression that the post-puerperal type of case was the most important economically, while Anderholm (1958) and Stach (1957), who studied approximately

equal numbers of first degree and more serious cases, both had some originating thus, with others beginning after or evidenced by the failure of service. Renner (1956) was quite clear that a state of complete anoestrum existed, with small hard quiescent ovaries, in one-third of his 91 cases, while Lundgren (1947), Thygesen (1948), and Rasbech (1954) were also definite that in the third degree condition the post-partum anoestrous period was prolonged beyond the normal.

Dawson (1949, 1951) pointed out that the accumulation of uterine "pus", sterile except for a few organisms from the normal vaginal flora, had been produced experimentally both in the mouse (Weinstein, Gardner & Allen, 1937), and in the heifer, by inhibition of the oestrous cycle (in these examples through the effect of exogenous oestrogen). He suggested that the numerous field cases of organism-free bovine pyometra might be of similar primary origin, and described all his 74 cases of purulent endometritis (20 with accumulative tendencies) as associated with complete failure of the oestrous cycle, usually following the puerperium. On his evidence this failure, however caused, was the primary lesion. Like Wunner (1950) in Germany he distinguished here two subgroups, the smaller of which yielded only low numbers of normal vaginal flora such as *E. coli* and had a good breeding prognosis on resumption of oestrous cycles. The larger group according to both these authors invariably yielded very large numbers of *C. pyogenes*, and the prognosis for future breeding was bad. Dawson gave reasons for still considering *C. pyogenes* in this rôle as a secondary facultative pathogen requiring "x-factors" (Lovell, 1937, 1943) to be present also before it would precipitate disease. Rasbech (1954) considered that the puerperium was the natural time during which such latent organisms might be expected to fulminate. It is interesting that very few clear records exist of *C. pyogenes* occurring in other circumstances associated with endometritis, such as in moderate numbers from pus flakes in oestrous mucus. Conversely, records of other organisms in vast numbers inhabiting anoestrous pus accumulations are almost as rare, though *Trichomonas foetus* can do so and perhaps *Ps. pyocyanea*.

If it be accepted that the severer forms of endometritis arise in connection with a delay in resumption of oestrous cycles following calving, possible causes of this delay, conceivably equivalent to an "x-factor" for *C. pyogenes*, require consideration. Dawson (1949) suggested that primary infection, as with *Br. abortus*, mechanical parturition damage, and an unknown cause resulting in placental retention were all important. Nielsen (1949) quoted evidence indicating that poor war-time feeding could enhance the effect of chronic brucellosis, and Lundgren (1947) considered a dietary deficiency was the prime cause, "leading to pathogenic activity in previous saprophytes". Kurchikov (1957) in Russia, besides mechanical damage, blamed overall nutritional imbalances, lack of exercise, and "excess of concentrate", which last suggests some element of lactational strain. Evertz (1955) more explicitly noted that treatment failed most often in animals in their second lactation and again in the five to eight-year-old group, which were associated with peak milk yields. Jørgensen (1959) found an abnormally high incidence of puerperal infections

among heifers in progeny-testing stations, immature growing animals under management for a maximum yield. Steinborn (1956) also observed that the prognosis of endometritis was worse in high yielders, these proving relatively resistant to treatment, and Renner (1956) stated briefly that the cause of this disease often seemed associated with occupational stress. Koch, Beck & Heim (1958) claimed to observe a hereditary tendency, in animals of "weak endocrine constitution" (Lagerlöf, 1949), which seems to imply a tendency to excessive lactation in stock with inadequate feed conversion ability. The high incidence of apparently causeless retained placenta cases progressing into purulent endometritis, which Dawson (1949) earlier observed, could have an explanation consistent with this stress theory in some experiments by McDonald, Nichols & McNutt (1954) and Hays & McDonald (1957). McDonald succeeded under controlled conditions in producing retained placenta at will in subjects ovariectomized late in pregnancy, by withholding exogenous progesterone supplements during the last 25 days before term. In a later experiment none of the (intact) dams of twins receiving a progesterone supplement, but all of the control twins' dams, retained their placentae. It may be that in high-yielding cows there is competition between the mammary gland and the mature placenta for the limited supply of progesterone available.

Hignett (1953) suggested that quite a separate factor, iodine deficiency or thyroid insufficiency, might produce the same results. He described the effect of thyroidectomy in cows and similar effects in hypothyroid animals. Besides poor udder development and yield there was a high incidence of uterine subinvolution, retained foetal membranes, and chronic purulent endometritis with *C. pyogenes*. Allcroft, Scarnell & Hignett (1954) further described three field outbreaks of hypothyroidism characterized by significantly lowered values for blood organic iodine and by excessive abortions, stillbirths and post-puerperal endometritis. Filsinger (1955) distinguished 250 of hyperthyroid and 400 of hypothyroid type among 1,600 cows, the type-incidence to a certain extent corresponding with the breed. The two types were attributed to a varying congenital hormone productive capacity of the individual's thyroid, and, consistent with the British observations, the incidence of second and third degree endometritis among hypothyroids was double that in the hyperthyroid group, with, furthermore, four times the incidence in the former of permanent infertility. Presumably during periods of iodine deficiency, such as may be caused by a wet season locking this element in the soil, the hypothyroid types are the first to suffer.

THERAPEUTIC METHODS USED AGAINST ENDOMETRITIS

The methods applied have involved mainly the local application of drugs to the endometrium. The chief groups of drugs employed have been chemical disinfectants or counter-irritants, reproductive hormones, and antibiotics.

Chemical Disinfectants

Lugol's iodine continued to be employed as it had been earlier. In dilutions of 1:500–1:1,000 it was reported ineffective by Rottensten &

Kierkegaard (1954), but at 1:200 it was considered useful by Pietzsch (1958), Pundt (1950), Evertz (1955), and Ohm (1955); Hemnell (1954) and Anderholm (1958) also had some confidence in iodine. Pietzsch, however, found that a saturated solution of common salt gave slightly better results. Schlaak (1951) used an ethereal oil for endometritis but with poor results. Pundt (1950) considered that "Otrhomin", which contained 19 per cent thiocyanic acid and 45 per cent hexamethylene tetramine gave rather better results than iodine. Kliemann (1953) was apparently using the same drug, although it was named "amino-weidnerit". On local application he was able to detect thiocyanic acid in the blood and at a higher level in the vaginal mucus over six days. Given by mouth, the drug did not produce detectable levels of thiocyanate in mucus. Nitrofurazone or furacin compounds were tried by Anderholm (1958), Lindley & Hatfield (1952), and Vigue, Fitzgerald & Castrucci (1959); they were also used by Koch, Beck & Heim (1958) in association with oestrogens. Anderholm (1958) claimed that 0·06 per cent aqueous nitrofurazone, "Nifuzon", gave better results than Lugol's solution (1:200). Finally, among synthetic chemicals, a variety of sulphonic derivatives have been applied. Steinborn used a methyl condensation product of metacresol sulphonic acid, "Lotagene", in 2 per cent strength, obtaining slightly better results than with iodine. Waddington (1951) and Orton (1954) used phenyl mercuric dinaphthyl methane disulphonate, "Penotrane", on a few cases, and Stach (1957) used the 4-amino benzol-sulphothiocarbamide salt of 4-amino methyl benzol sulphonamide under the name of "Marbadal". Easley *et al.* used sulphamezathine and sulphamerazine without effect, while Dawson (1951) tried sulphanilamide, and 4,4-diamidinodiphenoxypropane di-β-hydroxyethane sulphonate (propamidine) in 0·15 per cent solution. Gathmann (1958) described the use of arsenic and plant extracts as tonics administered by systemic routes, and Butayeva (1958) recommended carbamyl choline as an adjuvant to oestrogens (see below).

Oestrogens

Although Rowson & Spriggs advocated the parenteral use of synthetic oestrogens for pyometra as early as 1942, Lundgren's paper in 1947 seems to be among the earliest publications on their use for endometritis accompanied by abnormal discharge, though these preparations were certainly being quite widely used both parenterally and as an intra-uterine application three or four years earlier. Lundgren used doses of stilboestrol dipropionate up to 100 mg., which he found excessive, and claimed good results and no undue side-effects. Dawson soon after published results (1949) in agreement with these findings, but Baurle (1950) who used in 60 mg. doses a different oestrogen, dimethoxy instead of dioxystilbene, to obtain a more prolonged effect, found it produced cystic ovaries in some of the cases treated and worsened other cases which were cystic at the outset, without ever obviously benefiting the uterine condition. Rowson, Lamming & Fry (1953) had good results from oestrogens in experimentally-produced purulent endometritis. Butayeva (1958) recommended up to 150 mg. of a synthetic oestrogen, Synoestrol, with

carbamyl choline for latent chronic endometritis. Wilson (1953) agreed with Baurle that parenterally administered synthetic oestrogen could often inappropriately induce cystic ovaries, sometimes in as small a dose as 25 mg. He therefore advocated local application, which he claimed had, in any case, a better effect on the uterus. Koch & Heim (1955) reported the use of intrauterine dienoestrol diacetate along with furacin on 85 cases, and they claimed good effects from 25–50 ml. of an emulsion preparation of 6,000 international oestrogen units per gram. Renner (1956) treated a similar series of 91 animals and claimed that in no case were cystic ovaries induced; Koch, Beck & Heim (1958) showed that results were little affected by omission of furacin. Butayeva (1958) also used natural oestrogen (15,000 i.u.), and found "folliculin" had an effect three times as lasting as that of Synoestrol in raising uterine tone and sensitizing the uterus to the action of carbamyl choline.

It is not clear how oestrogens take effect upon endometritis. Although Faulkner (1943) showed that diethylstilboestrol and hexoestrol were directly bactericidal *in vitro*, particularly to *Corynebacteria*, the natural oestrogens, oestradiol and oestrone, had no bactericidal properties. Yet the good effects observed of "oestrus" on endometritis are not necessarily to be attributed simply to the direct disinfectant properties of the stilbene compounds. Lundgren (1947), Nielsen (1949), and Dawson (1951) all note a good effect from restoration of oestrus without recourse to synthetic compounds, whether spontaneous, by mechanical stimulation of the cervix or as a result of expression of the corpus luteum. It might be that a normal *alternation of phase* in the endometrium has a more specific effect against pathogens than direct bacteriostasis by synthetic agents, especially as large doses not only of natural but also of synthetic oestrogen (Blakemore, 1946), can have the effect of blocking the oestrous cycle and inducing the accumulation of uterine pus. Certainly the good effects even of the synthetic oestrogens seem to be confined to cases with this complete failure of cycle and purulent tendencies—thus Baurle's (1950) series included none of these and no benefit resulted from oestrogen therapy. An effect from hormonal shock therapy upon the sluggish pituitary might be postulated. On the other hand Koch & Heim (1955) and Lundgren (1947) claimed to cure endometritis with synthetic oestrogens even when the cases were already affected with cystic ovaries, which cure could then be more readily attributed to direct disinfectant action than to any hormone shock effect on the pituitary. The occurrence of severe endometritis in the natural presence of cystic ovarian disease, in which there is often excess natural oestrogen production (e.g. Velle, 1958), as recorded *inter alia* by Lundgren, Koch & Heim, and Dawson, underlines the importance of separate assessment of the effects of natural and synthetic oestrogenic compounds. Further treatment trials using the natural oestrogens would be of both theoretical and practical interest.

Antibiotics

Although antibiotics were undoubtedly being used against bovine endometritis by 1946–47, the report by Easley *et al.* (1951) is apparently among the first to be published on this subject. Easley *et al.* used 200,000 units

of penicillin, with or without 1 gram of streptomycin and one or two sulphonamide compounds. Each of these combinations seemed to have some good effect. Moulin (1952) used 100,000 penicillin units at insemination time; his results were indefinite. Hoppe (1955), however, found 400,000 units penicillin with 1 gram streptomycin useless given at insemination time, though Hemnell (1954), using 300,000 penicillin units with or without a half gram of streptomycin, obtained rather more encouraging results both at and between oestrous periods. These four experiments were almost entirely on first degree cases, whereas Merkt (1953), Evertz (1955), Genegal (1955), and Stach (1957), also treating second and third degree cases, employed larger dosages. Merkt used a minimum dose of half a million units, sometimes repeated after 24 hours, sometimes together with a similar dose of streptomycin; his most satisfactory preparation was one supplying 400 mg. penicillin in ointment form. Evertz and Genegal both found that one million units of procaine penicillin gave better results than Lugol's iodine, while Stach returned to the formula of synergism with sulphonamide compounds, using 250,000 penicillin units with the 4-amino benzol sulphothiocarbamide salt of 4-amino methyl benzol sulphonamide (Marbadal) and usually 0·25 g. streptomycin also. Streptomycin alone has been used in cases of purely purulent endometritis by Rasbech (1954), who advocated 20–40 ml. (1–2 g.) doses of 5 per cent solution, and by Boller (1954), who preferred a larger volume, two doses of 2 g. in a one per cent solution. Oxytetracycline was found promising in first degree cases by Sacchi, Smith & Tower (1958); they used it at oestrus or 24–72 hours later in a dose equivalent to 100 mg. of biological activity. Link (1956) claimed that 543 of 548 cows he treated with terramycin bred again but a series of untreated controls was not maintained. Merkt compared the value of oxytetracycline with penicillin, giving 1 gram on each of three consecutive days, but he found little to choose between the two agents. Both Ohm (1955) and Genegal employed on cases of all degrees 426 mg. aureomycin sulphate in 7·1 grams of ointment base; it seemed superior to Lugol's iodine, giving results about equivalent to those from a million units of penicillin. Merkt found aureomycin ointment superior to aqueous penicillin. Easley *et al.* (1951) used aureomycin and bacitracin inconclusively on a few cows, and Munker (1955) carried out an aureomycin trial, finding it as effective as penicillin/streptomycin against *C. pyogenes* and much superior in non-specific infections. Polymyxin B, 96,000 units with bacitracin, 4,800 units, was chosen by Smith (1957) for use on first degree cases within 48 hours of service; 69 out of 76 infertile cows conceived after treatment, but no controls were left. Some synergism between these two antibiotics, at least under *in vitro* conditions, had been claimed.

The Timing of Treatment in First-Degree Cases

It is obviously convenient to treat and inseminate a cow at one and the same visit, other things being equal. However, recent work on uterine neuromuscular physiology, which has been summarized by Dawson (1959), has indicated that during oestrus the uterus undergoes violent tetanic muscular spasms, associated with the rapid upward

transport of spermatozoa; and Skjerven (1954) was able to show, by a clamping technique at laparotomy before slaughter, that when 30–120 ml. of 15 per cent aqueous barium sulphate was injected during oestrus, no trace of it remained in the uterus after 24 hours. Cattle injected similarly at from 27–72 hours post-oestrum showed that progressively more liquid remained in the uterus as the interval increased. At 24 hours one animal had medium not only in the oviducts but in the ruptured follicle as well. However, during the luteal phase proper, the amount of medium found in the uterus corresponded with that injected. Hence it appeared to Skjerven that liquid disinfectants given at oestrus would be unlikely to remain long enough in the uterus to influence endometritis; their upward transit might also prejudice the downward passage of the ovum. The results obtained by Hemnell (1954), Merkt (1953), and Sacchi *et al.* (1958) all seem consistent with this theory. The latter group mentioned simply that results were rather better from treatment 24–72 hours post-oestrum, than at insemination. Hemnell obtained conception rates from first insemination of respectively 59 and 65 per cent when penicillin treatment was applied at and between heats; with smaller numbers given penicillin/streptomycin treatment, the difference was greater in favour of between-oestrus treatment, respectively 40 and 71 per cent, and Merkt obtained comparable figures of 40 and 74 per cent, irrespective of whether penicillin or aureomycin was used. Hemnell found no difference in conception rates with Lugol's iodine given between or during oestrous periods, which suggests that it is uterine disinfection and not ovum transport which is most prejudiced by treatment during oestrus. Fresh evidence that the iodine has a *counter-irritant* rather than disinfectant action was provided by Nielsen (1949), who found peaks of conception following treatment at the seventh and 29th days, indicating a reset cycle, with oestrus induced by the treatment after a week's interval. Further experimental work on the fate of radio-opaque medium injected at various stages of the cycle was published by Bu & Skjerven (1959). This confirmed Skjerven's earlier findings, in particular showing that the amount of medium flooding the oviducts when injected during or soon after oestrus increased with the size of the dose injected, although it was suggested that even 20 ml. doses might prejudice fertility if injected at the wrong time.

THE CONTROL OF TREATMENT

There is a natural tendency on the part of clinicians to ignore the effect of the *vis medicatrix naturae* in resolving cases of endometritis. Percentages of pregnancies after treatment are usually reported with the tacit assumption that the treatment applied has largely been responsible. However Dawson (1951), working with third-degree cases associated with *C. pyogenes*, most of which arose following calving, showed that of 25 controls left untreated, only 12 continued indefinitely with the disease in the *status quo*, while three improved clinically, and as many as ten recovered naturally and bred again without much loss of time. The highest incidence of natural recovery occurred from three to six weeks after calving. Such observations may be thought to limit the value of

the therapeutic claims made for instance by Waddington (1951) and by Orton (1954) for phenyl mercuric dinaphthyl methane disulphonate, as a great majority of the cases they reported were treated less than 24 days after calving. Therapeutic results on cases of not less than six months' standing (as reported for example by Evertz, 1955), demand more serious consideration, but even here the effect of the essentially slow process of unassisted endometrial regeneration cannot be ignored. Thus Schulz & Grunert (1959) showed that this process continued up to the 12th week after calving even in normal healthy cattle.

In attempting to assess the true value of any particular method of treatment, therefore, the maintenance of an adequate proportion of typical cases as untreated controls must be of cardinal importance, although comparison of the effects of different types of treatment on similar cases is not without a certain value.

Treatment of First-Degree Cases

Five interesting experiments thus controlled have been completed mainly or entirely upon cases of the first degree. One trial by Hoppe (1955) involved 117 "symptomless repeat breeders" treated with antibiotics, and 1,432 controls; conception rates after one insemination were respectively 58 and 57 per cent. With groups of 346 and 382 there was no significant difference, with 51 and 50 per cent rates. Again, in work involving 57 similar cows, Ulberg, Black, Kidder, McDonald, Casida & McNutt (1952) found no difference between controls and those given aureomycin and penicillin during oestrus. However it does not necessarily follow, in the light of Bu and Skjerven's (1959) results, that the treatment was in itself ineffective, since it was given only at insemination time. Sacchi *et al.* (1958) obtained very different results, although only some of their cases were treated 24–72 hours after heat, 219 treated cows having a conception rate of 70 per cent after one insemination, while 67 controls required "twice as many inseminations", equivalent to a rate of only 35 per cent. But Rottensten & Kierkegaard (1954) noted no difference in the rates after the fourth insemination (42 per cent), irrespective of whether or not treatment with Lugol's iodine (at all stages of cycle) had been given after the first three services. The extent to which these results conflict is reduced by the circumstance that antibiotics and iodine take effect in different ways. Furthermore Rottensten & Kierkegaard used iodine in unusually low concentration. The work of Sacchi *et al.* may then provide the only available evidence on the question whether "symptomless repeat breeders" are actually affected with endometritis, indicating that such is the case in an important proportion of cases. Hemnell's results (1954) on cases with abnormal oestrous mucus appear to support those of Sacchi *et al.* Forty-five "controls" receiving only placebo treatment gave a conception rate of 45 per cent after the first insemination, while 20 cases receiving Lugol irrespective of cycle stage had a rate of 60 per cent and 26 treated with penicillin between oestrous periods had one of 65 per cent. Despite the small numbers of cases these results are of special interest as clearly differentiating between antibiotic treatment during oestrus and at other times.

The animals studied by Easley *et al.* (1951) were clearly affected with endometritis on the evidence of bacteriological examination before and after treatment. Their status may have been on the borderline between the first and second degrees, as the majority had been served seven or eight times, and the time of antibiotic treatment was also equivocal, usually 24 hours after heat. Of these animals 21 untreated controls showed a conception rate after first or second service of 30 per cent, while three antibiotic-treated groups of 16, 22, and 20 showed rates of 56, 59, and 80 per cent. Thus the consensus of evidence from controlled trials favours the view that antibiotic treatment and perhaps also that with iodine is quite effective against first degree endometritis.

Evertz (1955) and Ohm (1955) compared the effects of Lugol's iodine and antibiotic treatment. They agreed that the two treatments were equally effective on first degree cases, 80 per cent of Evertz's subsequently breeding in each treatment group. Iodine was less effective than antibiotic in second and third degree cases, only 50 per cent of Evertz's treated with iodine breeding again, while 67 per cent of those treated with penicillin bred again. Ohm's comparable figures were 55 per cent and 64 per cent respectively, though, overall, including first degree cases he found 78 per cent of those treated with iodine bred again compared with 85 per cent after aureomycin. These workers' results provide some indirect evidence in favour of iodine treatment for the milder cases, in view of the controlled results of similar antibiotic treatment discussed above. Steinborn (1956) tested iodine against his metacresol sulphonic acid derivative. Again it proved equally effective in first degree cases but inferior when endometrial damage was more severe. Stach (1957) found that with added streptomycin 88 per cent bred again, while with cases treated only with penicillin and Marbadal (see above) this figure was reduced to 69 per cent. His *in vitro* tests showed streptomycin was the most active agent against the recovered bacteria but that the effect of the others was more persistent. There was marked synergism against certain genera but only streptomycin was really active against staphylococci.

Treatment of Second and Third-Degree Cases

The comparisons made by Evertz, Ohm, and Steinborn provide indirect evidence, again, on the efficacy of treatment in second and third degree cases. Direct trials including comparisons of untreated controls with animals discharging continuously and treated have been few. Dawson's series (1951) of 25 untreated *C. pyogenes* cases has been discussed, disease persisting unaffected in about 50 per cent. A further 87 treatment trials on such cases were distributed between Lugol's iodine, oestrogens or corpus luteum enucleation, local sulphanilamide, propamidine, and combinations of the latter three (Dawson, 1951). Results indicated that sulphanilamide, propamidine, and endocrine treatment all had a good effect on the condition, even in cases of long standing, the combination of endocrine methods with propamidine appearing to be the treatment of choice. Twenty-three trials with iodine were in no single case followed by any improvement, but after the other treatments 25 per cent of unselected cases bred again.

Bacteriological sampling before and after treatment in each case indicated a particularly rapid direct disinfectant action by propamidine; with effective treatments the transition was very marked between purulent discharges containing innumerable organisms and mucous samples which were organism-free or yielded only a few contaminants or genera of the normal flora. Later Rowson *et al.* (1953), working not on field cases of *C. pyogenes* but on those experimentally induced (also incorporating, however, a proportion of untreated controls), again demonstrated the ineffectiveness or worsening effect of iodine treatment in these circumstances. Before either British experiment Lundgren (1947) had recorded his impression that the use of iodine retarded healing in cases of this type. Similarly Boller (1954) and Munker (1955) reported iodine treatment as useless against animals affected with *C. pyogenes* or *Ps. pyocyanea*. In over 40 second and third degree cases where *C. pyogenes* was not involved, Dawson (1951) could detect no significant difference between the organism content of samples taken before and after treatment, but Koch *et al.* (1958) found that haemolytic staphylococci were removed by oestrogen treatment while the *B. proteus* and anthracoid content were unaffected. Evertz (1955) also found penicillin treatment had no influence on *B. proteus*. The specialist literature on *Ps. pyocyanea* indicates that polymyxin B and neomycin are the only effective antibiotics against this genus. Merkt (1953) noted that other antibiotics as used by him had no effect, and Vigue *et al.* (1959) found nitrofurazone equally useless. Boller found streptomycin effective against 14 out of 16 *C. pyogenes* cases on the evidence of cultures before and after treatment, but many of these cases were treated within five weeks of calving. Agrimi *et al.* (1959) were also favourably impressed with streptomycin treatment, and Munker (1955) found aureomycin gave fair results against this organism. Beer (1959) however, showed that *C. pyogenes* was unaffected by neomycin and he considered it was generally rather resistant to antibiotics. Bulling (1954), with special reference to streptomycin, was inclined to agree, as also was Hardenbrook (1958). Contrary to the general opinion, Hardenbrook and Agrimi *et al.* favoured the use of iodine irrigations against *C. pyogenes*. There seems to be a strong case for more extended use of 4,4-diamidodiphenoxypropane di-β-hydroxyethane sulphonate (propamidine) under the conditions of its controlled trial, namely three irrigations within a period of six days.

ANTIBIOTIC PROPHYLAXIS AGAINST ENDOMETRITIS

A number of workers, mainly in America, have inquired into this possibility. Some of their results are shown on p. 452, Table IV, from which the indications are that any of the drugs used will affect conception rate irrespective of the method of administration. In herds which already have a truly normal conception rate (less than two services per conception in controls) the effect of the antibiotic seems usually (not in Buckalew and Alford's [1958] experiment) to be slightly adverse, possibly through destruction of normal bacterial flora which assist in uterine metabolism. Besides the tabulated results, a further trial briefly reported by Hienze (1958) also revealed

similar adverse effects. But in four units requiring more than two services per conception in controls, the antibiotics were markedly beneficial, presumably on account of the existence in these herds of a low-grade infection problem, as indeed the history of *V. fetus* incidence in the material of Jørgensen (1959) and Stula *et al.* (1958) has confirmed.

SUMMARY AND CONCLUSIONS

The view has persisted that chronic endometritis is a very important condition economically. Richter's classification (1926) has been extended in more detail, with some agreement that his first degree cases can be divided usefully into those with no symptoms beyond failure to conceive, and those exhibiting intermittent discharge, especially at oestrus. A second degree subgroup with a bad breeding prognosis after trichomoniasis has been noted and there is some evidence that third degree cases are often primarily organism-free but apt to be secondarily infected, mainly with *C. pyogenes*. There has been substantial progress in bacteriological studies, including this aspect among others, of the control of treatment, though too much effort has continued to be expended on completely uncontrolled treatment trials. Staphylococci, especially haemolytic forms, appear to be the main pathogens in first and second degree cases, with probably streptococci and haemolytic strains of *E. coli* also playing important parts. In third degree cases *C. pyogenes* is of outstanding importance; its development of pathogenic properties seems to be linked closely with stasis of the ovarian cycle, possibly resulting sometimes from lactational strain or on other occasions from thyroid inadequacy. Preparations used in treatment have been applied mainly locally; counter-irritants, chemical disinfectants, oestrogens and antibiotics have been the chief agents. For first degree cases fresh evidence supported the view that Lugol's iodine remains quite an effective treatment but various furan and sulphonic derivatives may be somewhat superior; this is more clearly established in relation to second and third degree cases. Since 1947 reports have been published on the good uterine effect, in such cases, of a restoration of the oestrous cycle, whether spontaneous, procured by mechanical methods, or by the use of synthetic oestrogens. How such treatment takes effect remains obscure although synthetic as opposed to natural oestrogens have a direct bactericidal action. Reports of the good effect of antibiotics were appearing by 1951. Penicillin, streptomycin, aureomycin and terramycin all seem reasonably effective in single doses, as indicated by the results of controlled trials, though possibly less so when *C. pyogenes* is involved, but one trial suggested that at least one chemical agent was effective against this organism.

Obvious opportunities for future work include the more detailed study of case-series including bacteriological studies with special reference to the pathogenic effects of the staphylococci. Further trials might usefully be made of the value of 0·5 per cent Lugol's iodine solution, which is cheap, regarding time of application in relation to stage of oestrous cycle, in first degree cases; and the evidence is still conflicting on the effectiveness of antibiotics in cases showing no symptoms beyond return to service. Here again the stage of cycle

when treated seems to be an important variable. It may be emphasized in this connection that much evidence exists suggesting that interference in the early or even late luteal phases of repeat breeders is unlikely to have undesirable consequences, in contrast to the situation as it affects normal cattle (Black, Ulberg, Kidder, Simon, McNutt & Casida, 1953). The study of more untreated control series for second and third degree cases is also urgent. In view of the earlier work showing the importance of mechanical stimulation of the cervix in therapy, trials of antibiotics and other drugs should include control series of animals undergoing this manipulation as well as entirely untreated controls.

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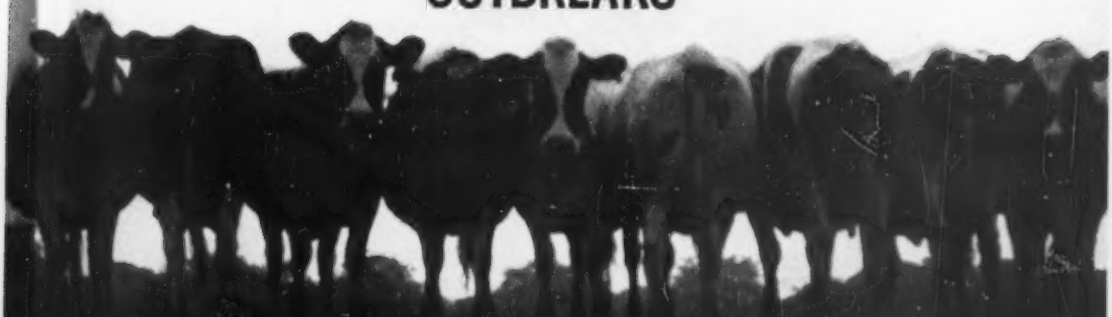

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STUDIES ON THE NORMAL AND ABNORMAL STRUCTURE AND FUNCTION OF THE OMASUM OF DOMESTIC CATTLE

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During examination of the gastrointestinal tracts of cattle slaughtered at this station it was found that many apparently healthy animals showed macroscopic changes in the omasum in the form of (1) adhesions between folds mediated by the presence of desiccated digesta, (2) depapillation of parts of folds, or (3) fenestration of parts of folds. This led to a study being made, the results of which are recorded in this paper.

Investigators of the function of the omasum have taken one of two views: either that the organ serves to triturate the food further after its earlier breakdown in the mouth, the rumen and the reticulum, or that the organ serves for the absorption of fluid. The literature related to the first has been reviewed by Favilli (1937) and Dukes (1955). Garton (1951) found that the concentration of inorganic phosphate, soluble calcium and magnesium in omasal liquor of slaughtered sheep was higher in all cases than the corresponding value for rumen liquor, lending support to the idea that one of the functions of the omasum is to absorb water. Gray, Pilgrim & Weller (1954) calculated that in the sheep 33 per cent to 64 per cent of water and 40 per cent to 69 per cent of fatty acids was absorbed from the digesta entering the omasum. Balch, Kelly and Heim (1951) considered that in dairy cattle digesta from the reticulum are, in the omasum, pressed against the folds and that these act like a sponge to allow fluid to penetrate between them. They considered also that the solid digesta, to be found between the folds, had been carried there suspended in that fluid.

Sinclair & Kunkel (1959) found that in lambs the degree of pigmentation of the mucosa of the rumen and the reticulum was directly related to the rate of body-weight gain. Favilli (1937) found that the epithelium covering the surface of the omasal folds and particularly that over the papillae was thin; underneath it there was a rich network of blood vessels, which structure he considered rendered the organ quite unsuited for trituration, but very much suited for absorption. He refers to Aggazzotti who considered that absorption of fluid did occur in the omasum. Habel & Biberstein (1952), describing the structure of the omasum, drew attention to the presence in the larger papillae of a "peculiar tissue that stains blue in haemalum-eosin preparations" which

they consider to resemble mucous connective tissue. Ramsay (1956) described necrosis of the epithelial surface of folds, with very little accompanying subepithelial inflammatory-cell infiltration, in the omasum of cattle affected with mucosal disease. Baker, McEntee & Gillespie (1960) recorded the presence of circular holes up to approximately 1·5 cm. in diameter in the omasal folds of calves with infectious bovine rhinotracheitis-infectious pustular vulvovaginitis virus; and the tissue adjacent to these holes was necrotic and infiltrated with neutrophils. Cohrs (1949) records that fenestration of the omasal folds may occur following a *Fusiformis necrophorus* infection secondary to foot and mouth disease, malignant catarrhal fever or rinderpest.

METHODS AND ANIMALS

A naked-eye examination was carried out, after washing with water, of the omasum of 576 cattle slaughtered at a Reading abattoir. These cattle were cows, beef bullocks and heifers, and a few bulls and young animals (about 1–2 years old).

A histological examination was made of the omasum of 134 cattle. Of these the ages of 123, slaughtered at this station, varied from new-born to 12 years; the ages of the remaining 11, slaughtered at Reading, were not recorded. The material was taken from areas of folds which appeared (i) normal, (ii) depapillated, (iii) fenestrated, (iv) scarred, and (v) coated with dry adherent food. It was fixed in 10 per cent formol-saline or, in a few cases, in Zenker's fixative. Sections were stained with haematoxylin and eosin, Van Gieson's stain or with polychrome methylene blue. Following the method described by Cooper and Schiff (1938), stained preparations were made of stripped-off omasal epithelium.

RESULTS

The normal appearance of the omasum: As pointed out above, differences in the colour of the rumen and reticulum of sheep have been described. Wide differences in colour, from straw-coloured to light slate-coloured, have also been found in the omasum of the cattle we examined. The outer wall of the omasum is remarkably thin, contrasting with the thickness associated with the well-developed muscular tissue in the wall and pillars of the rumen. Thus the organ consists almost entirely of about a hundred thin folds which protrude from their attachments to the wall like leaves of a book from the inside of a biconvex spine, free towards the sulcus omasi. Some of greater breadth reach the sulcus, while others, between these, reach only a greatly varying distance towards it. Of the folds reaching the sulcus, the broadest and longest are attached to the greater curvature and the others, lateral to these on either side, are progressively narrower and shorter. The two surfaces of each fold are studded with papillae. These papillae are nipple-shaped and tilted slightly to one side (see Figs. 1 and 6). Towards the reticulo-omasal orifice (proximal end of fold), they are large and may measure 4·5 mm. long and 2·5 mm. in diameter at the base, becoming progressively smaller towards the abomasal (distal) end, where they may measure 0·5×0·5 mm. They are much more crowded towards the distal end, compared with the

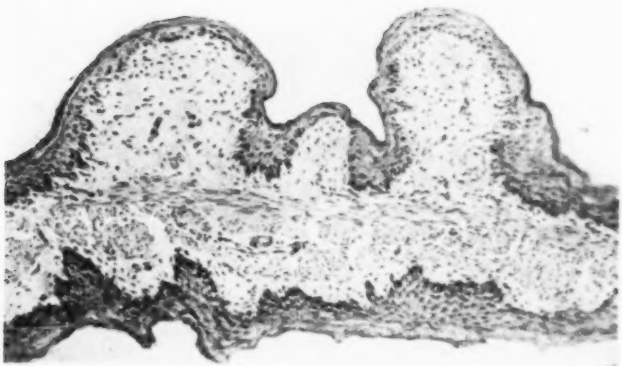
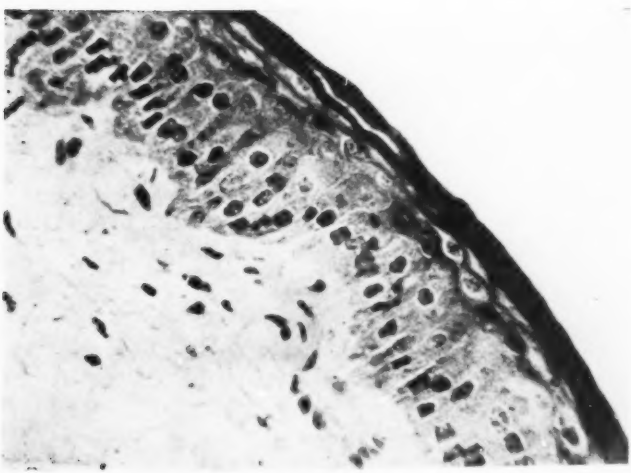


Fig 1. Section of omasal fold showing thinner epithelium over the papillae. H. & E. × 80.



2. Section of omasal papilla showing basal columnar cell layer with few cell layers over it. H. & E. × 250.

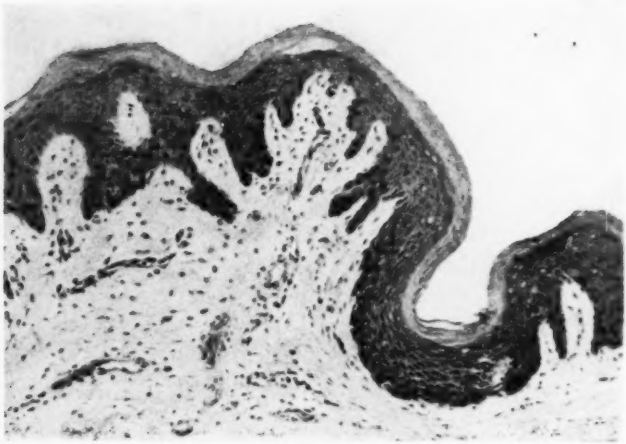


FIG 3. Section of non-papillated part of dorsal wall of rumen showing many cell layers in epithelium. H. & E. × 100.

FIG 4. Section of omasal fold showing strong rete-peg formation. H. & E. × 40.

proximal end. Actual counts on material from nine animals show two to four times more per square inch at the former than at the latter. The papillae on the proximal one-tenth or so of the surface of the large folds are provided with a horny, curved and pointed cap, which is ivory-white in colour and readily distinguished with the aid of a lens from the body of the papilla, as can be seen in Fig. 6.

The epithelium covering the uncapped papillae, such as that on the rumen papillae (see Dobson, Brown, Dobson & Phillipson, 1956), consists of a basal layer of columnar cells with very thin cell walls, and over this layer are only a few more layers of cells, which are in the process of becoming flattened and keratinized, as shown in Fig. 2. The epithelium over these papillae is thinner than that over the intervening tissue, as shown in Fig. 1, and, in stained preparations of stripped-off epithelium, it is seen to be more translucent than the remaining epithelium, again indicating a thinner structure. The epithelium of the capped papillae, on the other hand, is thickened under the horny cap and may show several layers of spinosa cells with their thicker cell walls and characteristic numerous small spines or bridges crossing, in these walls, from a cell to the adjoining one. In polychrome methylene blue sections the centre of the core of the uncapped papillae is stained metachromatically a reddish-purple and between this tissue and the epithelium is a very thin layer of blue-staining connective tissue. Under the cap of the horny papillae this latter tissue is thicker, with the result that in sections two zones are often seen: a reddish-purple one at the base of the papillae and a blue one under the cap. The cell nuclei of the former zone are usually fewer in number, more faintly stained and more irregularly outlined than the oval, regularly contoured nuclei of many of the cells of the latter (see Fig. 5). The reddish-purple-staining tissue may not be entirely confined to the core of the papillae as on occasion such tissue has been seen to extend a short distance from the base of a papilla into the adjoining connective tissue. It would appear to be the same tissue as that described by Habel & Biberstein (1952) as resembling mucous connective tissue. Ogilvie (1940, p. 80) describes mucoid and myxomatous tissue as staining faint blue with haematoxylin and deep reddish-purple with polychrome methylene blue. Under the epithelium covering the areas between the papillae the collagen supporting tissue is thin and contrasts with the thick collagen tissue to be found under the epithelium of the non-papillated parts of the dorsal wall of the rumen.

Abnormal omasal structure: Of the 576 animals mentioned above, 36·3 per cent showed adhesions involving two or more folds with dry food material between the adhering surfaces. On palpation these adherent folds feel hard in contrast with the yielding normal folds. The smaller folds lateral to the large central ones were more often affected. Patches of adhesions, or, alternatively, widespread adhesions involving most of the fold, may be met with. The surface of the adherent food next to the epithelium was often dark brown or black in colour and showed the imprints of the opposing papillae. The underlying tissue surface was slightly reddened or slightly cyanosed. In a few animals nearly all the folds were involved.

Of the 576 animals 47·9 per cent showed some degree of depapillation involving areas varying from about a square centimetre of the tissue adjoining the centre of the free edge of one or a few folds to areas of up to about 20 square centimetres around the centre of the free edge of several folds. Some degree of fenestration was seen in 15·9 per cent of the 576. This was more varied in its distribution within the folds than was the depapillation. A moderately affected fold is shown in Fig. 6. Occasionally almost the whole of one or even of many folds has been found to be disintegrated, presumably by the fusing of what were at first isolated fenestrae. Scar formation occurred in a few animals. A considerable amount of depigmentation around the centres of the free edges of folds was often found and also frequent over-pigmentation, especially in the distal parts of the folds.

On microscopic examination the adherent folds might show little change apart from a slight increase in the shedding keratinized layers. Cellular infiltration was not associated with the presence of adherent food, which, along with Ramsay's finding (1956) that little cellular infiltration was to be found under the necrosed epithelium in mucosal disease, may indicate that omasal fold tissue does not readily react by cellular infiltration. In some animals, where scar formation occurred, sections showed breaks in the epithelium and in these there was invasion of the surrounding tissues by phagocytes. A feature of the sections was the wide variations in the "rete-peg" (the projections from the inner surface of the epithelium into the propria) development met with in different animals. For an illustration of strong rete-peg formation, see Fig. 4. Though the most marked rete-peg formation occurred in a few old animals, it was not pronounced in all old animals. Also several young animals did show quite extensive rete-peg formation. Where rete-peg formation was only slight, it tended to occur most at the base of the papillae. This type of formation was sometimes more marked on one side of a fold than on the other. Although its occurrence was often marked in depapillated areas, this finding was not constant and also what appeared to the naked eye to be normal tissue might show considerable rete-peg formation microscopically. The epithelial cells composing the rete-pegs were of the spinosa type with the exception of the basal cells which are thin-walled. In our material the tissue around the fenestrae was not found to be necrotic or infiltrated with phagocytes.

DISCUSSION

It has been thought by some workers that the omasum serves as a triturating organ. There are good reasons for believing that this is not the case. Its very thin outer wall is not adapted for trituration. Also the thin epithelium over the folds contrasts with the much thicker epithelium to be found in the non-papillated area in the dorsal wall of the rumen (see Fig. 3) through which presumably little or no absorption takes place. This latter epithelium is supported by a thick layer of collagenous fibres whereas only a thin layer underlies the omasal epithelium.

Typically the digesta between the folds are finely divided, especially between the distal parts (Becker, 1937), and this would support the view of Balch *et al.*

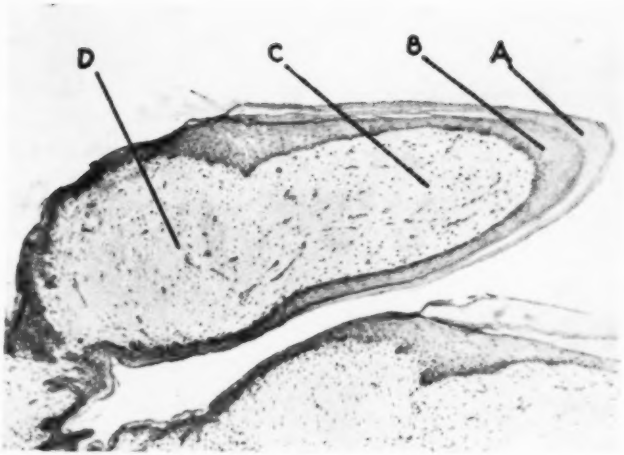


FIG 5. Section of capped papilla showing at:—
A. Horny cap.
B. Thickened epithelium under this cap.
C. Ordinary connective tissue.
D. Mucous connective tissue.
H. & E. × 100.

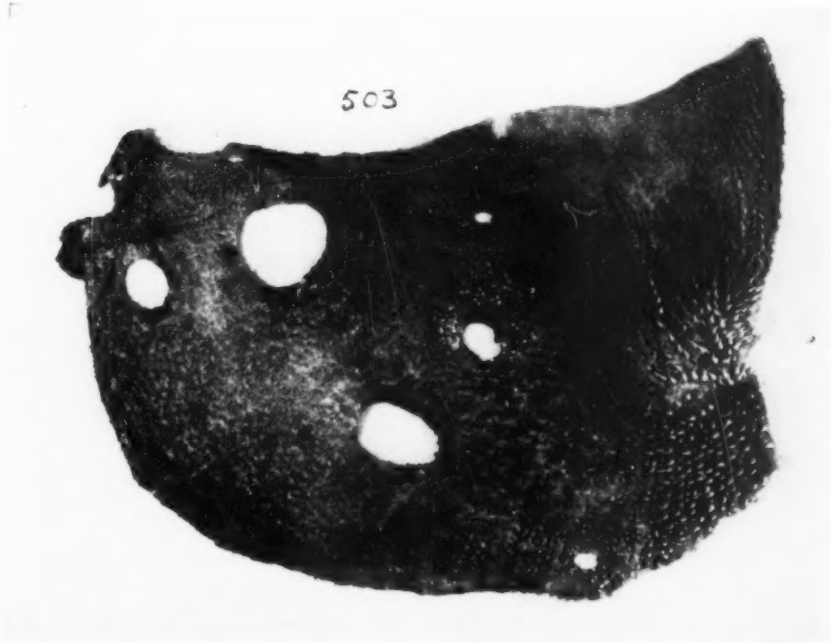


FIG 6. Moderately fenestrated omasal fold.

(1951) that such digesta are carried there suspended in fluid. Becker (1937) considered that the finer state of division of the digesta between the more distal parts of the folds indicated trituration by the omasum, but it is difficult to visualize how an organ with a structure such as the omasum could achieve this. It is more probable that the horny papillae at the proximal part of the folds serve to prevent much coarse digesta from entering between the folds and thus only finely divided material normally penetrates between the more distal parts. It was observed that in animals which judging from the appearance of the contents of the omasum had been fed chopped herbage, many pieces of this herbage had actually penetrated between the folds. Whole grains were also found between the folds in a few animals.

As very finely divided digesta usually composed the material between the adherent folds, it was thought that omasal damage might be associated with excess of such material reaching this area, and that this could possibly be avoided by feeding coarsely crushed seeds instead of the finely ground seeds which are often fed to cattle. Seven calves were therefore put on a diet of hay, crushed oats and crushed beans. This, however, did not prevent damage to the omasum as, of these seven animals, four showed slight depapillation or slight fenestration. Further studies would therefore be required to find out if omasal damage is related to diet, and if so, what types of diet most predispose to it. The possibility that fenestration is caused by a previous infection, such as those described by Baker *et al.* (1960) and Cohrs (1949), seems unlikely in the cattle at this station as they have not been observed to show illness suggestive of such infections.

These studies have not made clear the relationship, if any, between macroscopic changes and the extent of rete-peg formation. There was not a clear-cut relationship between the degree of depapillation and the extent of rete-peg development. Several old animals did show this formation extensively but others showed much less, and while most young animals showed only slight rete-peg formation others showed quite extensive changes of this kind. This formation seems to be in itself a response to a stimulus unrelated to the cause of depapillation or of fenestration. It is not clear, however, whether such a stimulus is a normal or an abnormal one. Strong rete-peg formation, such as is shown in Fig. 4, would appear to be definitely abnormal.

An interesting finding is the presence of mucous connective tissue in the core of the papillae. Ogilvie (1940) states that mucin has the property of absorbing water in large quantities. The main function of the omasum is considered by several workers to be the absorption of water, and it is thus possible that this type of tissue is especially adapted to aid this function. Thus depapillation of folds or the sticking together of parts of folds or whole folds may be detrimental to the animal's metabolism in depriving it of many of these absorbing units.

A feature of these studies was the frequency of adhesions between folds. There is a possibility that some of this may represent dysfunction brought about by changes of diet and the general disturbances associated with travel to markets, etc. It is evident that all adhesions could not be attributed to this

cause since some animals killed at this station were not subjected to change of diet or to long-distance travel and did show adhesions. Also hand-fed animals tended to show more extensive adhesions than did grass-fed ones. In the majority of the animals fed on chopped herbage and available for examination chopped digesta in a dried state were present between the folds. The presence of such material may be harmful to the animal, possibly by damaging the thin epithelium or inducing a tendency to adhesions.

How important the omasum is in the economy of the bovine animal is not known. The fact that a quite extensively damaged omasum may be found in an apparently healthy animal may indicate that it can readily adjust itself to such damage. On the other hand the complex structure of the organ and the fact that it is the second heaviest of the four parts of the stomach would indicate that it is probably an important organ and that damage to it, or interference with its functioning, may be a matter of moment.

SUMMARY

(1) Various aspects of the normal macroscopic and microscopic structure of the omasum are described.

(2) Special attention is drawn to the thin epithelium over the non-horny papillae and to the mucous connective tissue core of all the papillae; both of these probably aid absorption.

(3) A macroscopic examination of the omasum of 576 slaughtered cattle was made. Of these 36·3 per cent showed two or more folds stuck together by patches or a diffuse layer of dry food; 47·9 per cent showed some degree of depapillation of a varying number of folds, the area affected being that around the centre of the free edge; 15·9 per cent showed some degree of fenestration; a small number showed scar formation in one or more folds.

(4) A microscopic examination was made of material from the omasum of 134 cattle. The adherent folds did not show obvious microscopic change, except slight increase in shed keratinized cells. A wide range of rete-peg formation was found, the conditions of development of which were not clearly determined but very strong rete-peg formation would appear to be definitely abnormal. Scars were found in the folds of a few omasa and in such cases breaks in the continuity of the epithelium with infiltration of phagocytic cells into the surrounding tissues were found.

(5) The cause of the production, and the possible detrimental effect, of these abnormal changes is discussed.

ACKNOWLEDGEMENTS

We are indebted to Dr. W. S. Gordon, C.B.E., for making available material and facilities, to Mr. F. Summerfield, A.R.P.S., for the photographs and to Mr. M. Beck and Miss K. Bailey for technical assistance. Mr. A. Meade, M.B.E., very kindly allowed us facilities for carrying out work at the abattoir.

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(*Received for publication*, 26 *July*, 1960)

BOOK REVIEWS

Der Huf. H. RUTHE. 1ST EDITION. 194 pp. Jena: Gustav Fischer.

This first edition is an attractively produced volume of some 25 chapters. It is concerned essentially with horse shoeing and veterinary surgical shoeing. The final chapter deals with the shoeing of cattle.

Included are descriptions of the materials and methods involved in the shoeing of normal and abnormal feet, as well as the anatomy and physiology of the foot.

Such a volume is unlikely to have a market in Great Britain where there is very little scope these days for surgical shoeing. On the continent, however, where the volume of horse work in veterinary practice is still quite considerable this authoritative work will be of value to the veterinary student and farrier alike.

L. C. VAUGHAN

Lehrbuch der klinischen Diagnostik der inneren Krankheiten der Haustiere. (*Handbook of Clinical Diagnosis of the Internal Diseases of Animals*). J. MÒCSY, 6th edition, pp. 659. Jena: Gustav Fischer. D.M. 40.

The first three editions of this book were written by Professor Marek and published in 1912, 1922, and 1937. The fourth edition appeared under the joint authorship of Marek and Mòcsy in 1951 and the latest volume is under the name of Professor Mòcsy alone, the author being a Professor in the University of Budapest.

It begins with a section on making a general examination of the sick animal and then proceeds, section by section, to describe how each body system is examined in detail and the diseases which affect it.

This has always been an encyclopaedic work, packed with detailed information about disease, and intended by the authors as a work of reference for students and practitioners, in which they will find something about any disease they are likely to encounter. It is essentially a textbook of clinical diagnosis. It is far too vast to be dealt with in detail in a review and it must suffice to choose one or two sections of it to illustrate its contents and scope. There is a coloured plate of the electrophoresis pattern of the serum proteins of the foal, calf, horse, cow and sheep and a note on the value of this technique, when used along with other methods of study, in determining the pathogenesis and course of diseases. Allergic tests are described in detail, including the subcutaneous tuberculin test for cattle, although the intradermal test is acknowledged to be much simpler and more reliable; it seems time that the rarely used tests were omitted and the space used for better purposes. The ECG is discussed and there are tracings from horses and cattle; there are also drawings made with the use of the rhinolaryngoscope. Mange is described in a considerable section, illustrated by photographs of the disease in all the usual domestic animals, and in the dromedary. A student would be bewildered if he read through a book like this because he sees so many ways of doing things

and so many diseases that give a similar picture that without a guide to tell him which are the best methods and which the most likely conditions he must assuredly get lost. An encyclopaedic volume like this is useful mainly as a supplement to sound clinical teaching on the live animal in which the really common diseases are demonstrated "in the flesh", and also as a work of reference to be found on the bookshelves.

This was certainly a monumental work when it appeared in 1912. The present volume follows the lines of the first and the reviewer wonders whether the advances in veterinary medicine in the last 50 years have not been such that it is no longer advisable to try to gather so much into a single volume. Poisoning, for instance, occupies 12 pages of specially small print, and there are even sections dealing with diseases of fish and of bees. There is a mass of information about almost everything connected with veterinary diagnosis and the volume continues to be a very useful reference work.

E. G. WHITE

Standardmethoden der tierärztlichen Milchuntersuchung. (*Standard methods of examining milk.*) W. SCHÖNHERR, pp. 57. Jena: Gustav Fischer. D.M. 18.15.

This small handbook is written by the director of the Section for Milk Hygiene and Udder Diseases of the Institute for Research on Infectious Diseases of Animals in Jena. In the preface the author expresses regret that veterinarians in Germany are playing a decreasing part in the supervision of foodstuffs of animal origin, largely owing to lack of interest on the part of the profession in this special field and failure to develop the technical procedures required. Internationally, steps have been taken by such bodies as W.H.O. and F.A.O. to reduce the number of tests to a minimum and to standardize them so that the results obtained everywhere are comparable. This book gives details of the various tests that can be carried out on milk—microbiological, chemical and physical. The exact technique is given, together with the apparatus and reagents available in Eastern Germany.

In 1958 a seven-year plan to increase milk production by about 50 per cent was put forward and an Institute for the Study of Milk was established in Oranienburg. This book represents a basis on which universally applicable tests for Eastern Germany might be developed and perhaps later be specified by legislation.

The techniques described and illustrated by photographs include milk sampling; total bacterial counts; the resazurin test; cell counts; examination for *Brucella*, *Mycobacteria* and *Salmonella;* methods for determining the chemical constituents of milk and for the detection of effective pasteurization or sterilization, and finally, for the determination of specific gravity and freezing point.

The many coloured photographs may account for the high price of this book. It is a very useful reference work for the laboratory and should fulfil the author's intention of providing a basis for the development of standard methods of milk examination to be used by veterinarians concerned with the production and distribution of clean and safe milk.

E. G. WHITE

NEWS

UNIVERSITY OF GLASGOW

Mr. E. W. Fisher, B.SC.(Edin.), M.R.C.V.S., graduated PH.D. of Glasgow University on Saturday, 5th November, 1960.

VETERINARY SURGEONS ACT, 1948

Election of Members of the Council of the Royal College of Veterinary Surgeons.

In accordance with the provisions of the Veterinary Surgeons Act, 1948, five members of the said Council, who must be members of the Royal College, will be elected in 1961 by members of the Royal College residing outside the Republic of Ireland.

Five present members of Council will retire at the Annual General Meeting in 1961 and are eligible for re-election, namely:

R. F. Montgomerie, Esq., PH.D., B.SC., F.R.C.V.S.,
Wellcome Research Laboratories,
Langley Court, Beckenham, Kent.

G. Atkinson, Esq., M.R.C.V.S.,
4 Compton Grove, Nairn Road, Canford Cliffs, Dorset.

L. G. Anderson, Esq., D.V.M., M.R.C.V.S.,
49 Cambridge Street, Aylesbury, Bucks.

T. M. Mitchell, Esq., M.R.C.V.S., D.V.S.M.,
Briony, Meadowfield Road, Stocksfield-on-Tyne, Northumberland.

Professor R. Lovell, D.SC., PH.D., M.R.C.V.S., D.V.S.M.,
Royal Veterinary College, Camden Town, London, N.W.1.

The term of office of the five persons elected in the place of the five members retiring by rotation will be four years.

Nominations of persons for election to the Council must be submitted in writing on a form which may be obtained from the undersigned, and which must be returned to him duly completed on or before 31st January, 1961.

Each such nomination form must bear the signature of the proposer and seconder, who must not be present members of Council, and must be countersigned by the nominee.

W. G. R. OATES,
Registrar,
Veterinary Surgeons Acts, 1881-1948,
9 Red Lion Square,
London, W.C.1.

17th November, 1960.

H.M. OVERSEAS CIVIL SERVICE
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Mr. K. W. Aspinall, M.R.C.V.S., Deputy Director of Veterinary Services, Nyasaland, has been appointed Director of Veterinary Services, Nyasaland.

Mr. R. J. Isaacs, B.AGRIC.SC.(N.Z.), Livestock Officer, Nyasaland, has been appointed Senior Animal Husbandry Officer, Nyasaland.

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Mr. J. D. Rennie, M.R.C.V.S., D.T.V.M., Veterinary Officer, Nyasaland, has been appointed Senior Veterinary Officer, Nyasaland.

Mr. R. N. Sanders, B.V.SC., Deputy Director of Veterinary Services, Uganda, has been appointed Director of Veterinary Services, Uganda.

Mr. G. E. H. F. Stumph Lendner, has been appointed Veterinary Investigation Officer, Northern Region, Nigeria.

THE WELLCOME TRUST NEW MEMBER

Professor John McMichael, M.D., F.R.C.P., F.R.S., who holds the Chair of Medicine in the University of London at the Postgraduate Medical School, Hammersmith, has been appointed a Trustee of the Wellcome Trust in place of Sir Henry Dale, O.M., G.B.E., F.R.C.P., F.R.S., who retired from the Trusteeship in July, 1960, and was succeeded as Chairman by the Rt. Hon. the Lord Piercy, C.B.E. Professor McMichael's appointment became effective on the 10th October, 1960.

Sir Henry Dale will continue to serve the Trust in an advisory capacity as scientific consultant.

ADVERTISERS' ANNOUNCEMENTS

C. J. Hewlett & Son Limited wish to advise the veterinary profession that henceforth they will be known as C. J. Hewlett & Son, Division of Astra-Hewlett Limited, King George's Avenue, Watford. This change of name will not affect the Company's rights, obligations or undertakings, and will in no way alter existing policy. The division will continue within the framework of the organization to be directed and staffed by the same personnel as hitherto.

Smith Kline & French Laboratories Ltd., announce that they have purchased Tallents Farm, Kimpton, Hertfordshire. This property, which extends to 120 acres, will be developed as a Veterinary Research Unit, ancillary to the main laboratories at Welwyn Garden City and will provide facilities for the evaluation, under field conditions, of the Company's various products which are designed for the control of diseases of economic importance to the livestock industry.

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